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Contents

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editorial

Are Nuclear Reactions also Reversible Reactions?

If a particle and an antiparticle can produce photons, can collision of photons of different spins produce a particle and antiparticle, say an electron and a positron?

By solving this problem, one can know what happened in the beginning of creation. Breit and Wheeler had predicted in 1934, that this is possible. However technology had not advanced to produce very high energy experiments in those days. If two photons of very high energy can be smashed together, there is a possibility of creation of matter-at least an electron and positron with the high energy that is available, high energy photons can be produced. This photon-photon collides, which would convert energy directly to matter is viable today because the technology needed for such high energy experiments are available today though the prediction was made nearly eighty years ago. This experiment was tried by Steve Rose of the Department of Physics at Imperial College, U.K.

Pure Physics, Chemistry supported by Mathematics are very fertile even today. Research is an attitude of mind. One who can do very well in one field can do very well in pure science, technology (applied Physics) and in any field of applied research and again come back to theoretical Physics. One can join any field-theoretical work, experimental Physics or Chemistry for example; but dig deeper whenever you work.

Anil Ahlawat
Editor

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PHYSICS MUSING

Physics Musing was started in August 2013 issue of Physics For You with the suggestion of Shri Mahabir Singh. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / AIIMS / Other PMTs with additional study material.

In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / various PMTs. The detailed solutions of these problems will be published in next issue of Physics For You.

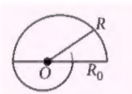
The readers who have solved five or more problems may send their solutions. The names of those who send atleast five correct solutions will be published in the next issue.

We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

By : Akhil Tewari

PROBLEM Set 12

1. A particle is rotating about a vertical axis in the horizontal plane such that the angular velocity of the particle about the axis is constant and is equal to 1 rad s^{-1}. Distance of the particle from axis is given by $R = R_0 - \beta t$ where t stands for time. The speed of the particle as a function of time is

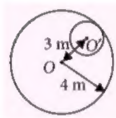


(a) $\sqrt{\beta^2+1}$
(b) $(R_0 - \beta t)$
(c) $\sqrt{\beta^2+(R_0-\beta t)^2}$
(d) β

2. n moles of a gas filled in a container at temperature T is in thermodynamic equilibrium with its surrounding initially. If the gas is compressed slowly and isothermally to half its initial volume, the work done by the atmosphere on the piston is

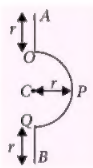
(a) $\dfrac{nRT}{2}$
(b) $-\dfrac{nRT}{2}$
(c) $-nRT\left(\ln 2 - \dfrac{1}{2}\right)$
(d) $-nRT\ \ln 2$

3. From a disc of mass 2 kg and radius 4 m, a small disc of radius 1 m with center O' is extracted. The new moment of inertia about an axis passing through O perpendicular to the plane of disc is



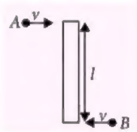
(a) 16 kg m^2
(b) 12 kg m^2
(c) $\dfrac{255}{16}$ kg m^2
(d) $\dfrac{237}{16}$ kg m^2

4. A wire frame $AOPQB$, lying in the horizontal plane, is free to rotate about a vertical axis passing through centre C of the semi-circle and perpendicular to plane of $AOPQB$. The mass M of the frame is uniformly distributed over its whole length. The moment of inertia of the frame about this axis, is ($OA = QB = r$ and $CP = r$ the radius of semicircular part)



(a) $Mr^2\left(\dfrac{14+3\pi}{3\pi+6}\right)$
(b) $Mr^2\left(\dfrac{\pi+r}{\pi+2r}\right)$
(c) $Mr^2\left(\dfrac{3}{4}\pi\right)$
(d) $\dfrac{1}{2}Mr^2$

5. Two particles A and B of mass m each and moving with velocity v, hit the ends of a rigid bar of the same mass m and length l simultaneously and stick to the bar as shown in the figure. The bar is kept on a smooth horizontal plane. The linear speed v_{cm} and angular speed ω of the system (bar + particle) after the collision are



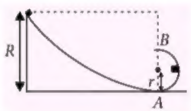
(a) $v_{cm}=0,\ \omega=\frac{12}{7}\frac{v}{l}$

(b) $v_{cm}=0,\ \omega=\frac{4v}{l}$

(c) $v_{cm}=0,\ \omega=\frac{5v}{l}$

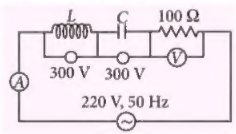
(d) $v_{cm}=0,\ \omega=\frac{v}{5l}$

6. A small block of mass m slides along a frictionless loop inside loop track as shown in figure. The minimum value of the ratio R/r so that the block may not lose contact at the highest point of the inner loop is



(a) $\frac{7}{2}$ (b) 2 (c) $\frac{5}{2}$ (d) 3

7. In the circuit shown in figure, what will be the readings of voltmeter and ammeter ?



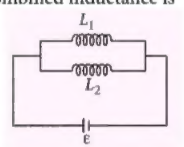
(a) 800 V, 2 A

(b) 220 V, 2.2 A

(c) 300 V, 2 A

(d) 100 V, 2 A.

8. Two inductances L_1 and L_2 are placed far apart and in parallel. Their combined inductance is



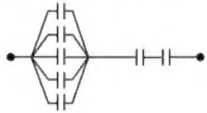
(a) $\frac{L_1L_2}{L_1+L_2}$

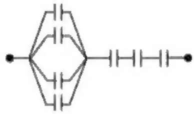
(b) (L_1+L_2)

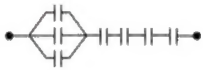
(c) $(L_1+L_2)\frac{L_1}{L_2}$

(d) $(L_1+L_2)\frac{L_2}{L_1}$

9. Seven capacitors each of capacitance 2 μF are to be connected in a configuration to obtain an effective capacitance of $\frac{10}{11}$ μF. Which of the combinations, shown in figure below, will achieve the desired result?

(a) 

(b) 

(c) 

(d) 

10. n identical cells, each of emf ε and internal resistance r, are joined in series to form a closed circuit. One cell A is joined with reversed polarity. The potential difference across each cell, except A, is

(a) $\frac{2\varepsilon}{n}$ (b) $\frac{n-1}{n}\varepsilon$

(c) $\frac{n-2}{n}\varepsilon$ (d) $\frac{2n}{n-2}\varepsilon$

SOLVED PAPER 2014

JEE Advanced

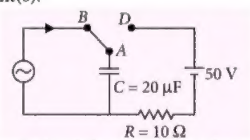
PAPER-1

SECTION-1

One or More Than One Options Correct Type

This section contains 10 multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which ONE or MORE THAN ONE are correct.

1. At time $t = 0$, terminal A in the circuit shown in the figure is connected to B by a key and an alternating current $I(t) = I_0\cos(\omega t)$, with $I_0 = 1$ A and $\omega = 500$ rad s^{-1} starts flowing in it with the initial direction shown in the figure. At $t = \dfrac{7\pi}{6\omega}$, the key is switched from B to D. Now onwards only A and D are connected. A total charge Q flows from the battery to charge the capacitor fully. If $C = 20\ \mu$F, $R = 10\ \Omega$ and the battery is ideal with emf of 50 V, identify the correct statement(s).



(a) Magnitude of the maximum charge on the capacitor before $t = \dfrac{7\pi}{6\omega}$ is 1×10^{-3} C.

(b) The current in the left part of the circuit just before $t = \dfrac{7\pi}{6\omega}$ is clockwise.

(c) Immediately after A is connected to D, the current in R is 10 A.

(d) $Q = 2 \times 10^{-3}$ C.

2. A light source, which emits two wavelengths $\lambda_1 = 400$ nm and $\lambda_2 = 600$ nm, is used in a Young's double slit experiment. If recorded fringe widths for λ_1 and λ_2 are β_1 and β_2 and the number of fringes for them within a distance y on one side of the central maximum are m_1 and m_2, respectively, then

(a) $\beta_2 > \beta_1$

(b) $m_1 > m_2$

(c) From the central maximum, 3rd maximum of λ_2 overlaps with 5th minimum of λ_1.

(d) The angular separation of fringes for λ_1 is greater than λ_2.

3. One end of a taut string of length 3 m along the x-axis is fixed at $x = 0$. The speed of the waves in the string is 100 m s^{-1}. The other end of the string is vibrating in the y direction so that stationary waves are set up in the string. The possible waveform(s) of these stationary waves is(are)

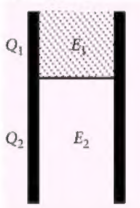
(a) $y(t) = A\sin\dfrac{\pi x}{6}\cos\dfrac{50\pi t}{3}$

(b) $y(t) = A\sin\dfrac{\pi x}{3}\cos\dfrac{100\pi t}{3}$

(c) $y(t) = A\sin\dfrac{5\pi x}{6}\cos\dfrac{250\pi t}{3}$

(d) $y(t) = A\sin\dfrac{5\pi x}{2}\cos 250\pi t$

4. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers 1/3 of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1. When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2. The electric field in the dielectric is E_1 and that in the other portion is E_2. Choose the correct option/options, ignoring edge effects.



(a) $\frac{E_1}{E_2} = 1$

(b) $\frac{E_1}{E_2} = \frac{1}{K}$

(c) $\frac{Q_1}{Q_2} = \frac{3}{K}$

(d) $\frac{C}{C_1} = \frac{2+K}{K}$

5. Let $E_1(r)$, $E_2(r)$ and $E_3(r)$ be the respective electric fields at a distance r from a point charge Q, an infinitely long wire with constant linear charge density λ, and an infinite plane with uniform surface charge density σ. If $E_1(r_0) = E_2(r_0) = E_3(r_0)$ at a given distance r_0, then

(a) $Q = 4\sigma\pi r_0^2$ (b) $r_0 = \frac{\lambda}{2\pi\sigma}$

(c) $E_1(r_0/2) = 2E_2(r_0/2)$

(d) $E_2(r_0/2) = 4E_3(r_0/2)$

6. A student is performing an experiment using a resonance column and a tuning fork of frequency 244 s^{-1}. He is told that the air in the tube has been replaced by another gas (assume that the column remains filled with the gas). If the minimum height at which resonance occurs is (0.350 ± 0.005) m, the gas in the tube is

(Useful information :

$\sqrt{167RT} = 640\ J^{1/2}\ mole^{-1/2}$;

$\sqrt{140RT} = 590\ J^{1/2}\ mole^{-1/2}$.

The molar masses M in grams are given in the options. Take the values of $\sqrt{\frac{10}{M}}$ for each gas as given there.)

(a) Neon $\left(M = 20, \sqrt{\frac{10}{20}} = \frac{7}{10}\right)$

(b) Nitrogen $\left(M = 28, \sqrt{\frac{10}{28}} = \frac{3}{5}\right)$

(c) Oxygen $\left(M = 32, \sqrt{\frac{10}{32}} = \frac{9}{16}\right)$

(d) Argon $\left(M = 36, \sqrt{\frac{10}{36}} = \frac{17}{32}\right)$

7. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter $2d$. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40 K?

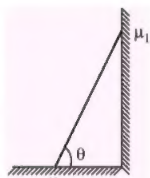
(a) 4 if wires are in parallel

(b) 2 if wires are in series

(c) 1 if wires are in series

(d) 0.5 if wires are in parallel

8. In the figure, a ladder of mass m is shown leaning against a wall. It is in static equilibrium making an angle θ with the horizontal floor. The coefficient of friction between the wall and the ladder is μ_1 and that between the floor and the ladder is μ_2. The normal reaction of the wall on the ladder is N_1 and that of the floor is N_2. If the ladder is about to slip, then



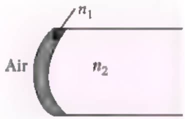
(a) $\mu_1 = 0$ $\mu_2 \neq 0$ and $N_2 \tan\theta = \frac{mg}{2}$

(b) $\mu_1 \neq 0$ $\mu_2 = 0$ and $N_1 \tan\theta = \frac{mg}{2}$

(c) $\mu_1 \neq 0$ $\mu_2 \neq 0$ and $N_2 = \frac{mg}{1+\mu_1\mu_2}$

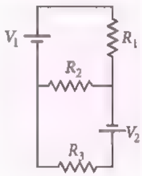
(d) $\mu_1 = 0$ $\mu_2 \neq 0$ and $N_1 \tan\theta = \frac{mg}{2}$

9. A transparent thin film of uniform thickness and refractive index $n_1 = 1.4$ is coated on the convex spherical surface of radius R at one end of a long solid glass cylinder of refractive index $n_2 = 1.5$, as shown in the figure. Rays of light parallel to the axis of the cylinder traversing through the film from air to glass get focused at distance f_1 from the film, while rays of light traversing from glass to air get focused at distance f_2 from the film. Then



(a) $|f_1| = 3R$
(b) $|f_1| = 2.8R$
(c) $|f_2| = 2R$
(d) $|f_2| = 1.4R$

10. Two ideal batteries of emf V_1 and V_2 and three resistances R_1, R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if



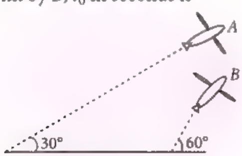
(a) $V_1 = V_2$ and $R_1 = R_2 = R_3$
(b) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$
(c) $V_1 = 2V_2$ and $2R_1 = 2R_2 = R_3$
(d) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$

SECTION-2

One Integer Value Correct Type

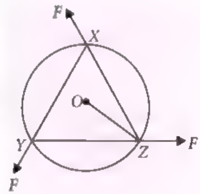
This section contains 10 questions. Each question, when worked out will result in one integer from 0 to 9 (both inclusive).

11. Airplanes A and B are flying with constant velocity in the same vertical plane at angles 30° and 60° with respect to the horizontal respectively as shown in figure. The speed of A is $100\sqrt{3}$ m s^{-1}. At time $t = 0$ s, an observer in A finds B at a distance of 500 m. This observer sees B moving with a constant velocity perpendicular to the line of motion of A. If at $t = t_0$, A just escapes being hit by B, t_0 in seconds is



12. During Searle's experiment, zero of the Vernier scale lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale. The 20th division of the Vernier scale exactly coincides with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the Vernier scale still lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale but now the 45th division of Vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2 m and its cross-sectional area is 8×10^{-7} m^2. The least count of the Vernier scale is 1.0×10^{-5} m. The maximum percentage error in the Young's modulus of the wire is

13. A uniform circular disc of mass 1.5 kg and radius 0.5 m is initially at rest on a horizontal frictionless surface. Three forces of equal magnitude $F = 0.5$ N are applied simultaneously along the three sides of an equilateral triangle XYZ with its vertices on the perimeter of the disc (see figure). One second after applying the forces, the angular speed of the disc in rad s^{-1} is

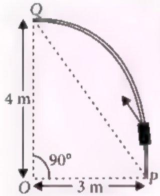


14. Two parallel wires in the plane of the paper are distance X_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance X_1 from one of the wires. When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1. In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2. If $\frac{X_0}{X_1} = 3$, the value of $\frac{R_1}{R_2}$ is

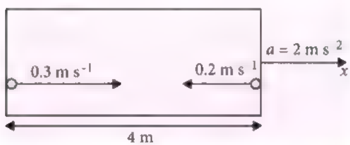
15. To find the distance d over which a signal can be seen clearly in foggy conditions, a railways engineer uses dimensional analysis and assumes that the distance depends on the mass density ρ of the fog, intensity (power/area) S of the light from the signal and its frequency f. The engineer finds that d is proportional to $S^{1/n}$. The value of n is

16. A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990 Ω resistance, it can be converted into a voltmeter of range 0 – 30 V. If connected to a $\frac{2n}{249}$ Ω resistance, it becomes an ammeter of range 0 – 1.5 A. The value of n is

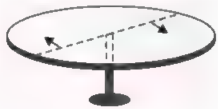
17. Consider an elliptically shaped rail PQ in the vertical plane with $OP = 3$ m and $OQ = 4$ m. A block of mass 1 kg is pulled along the rail from P to Q with a force of 18 N, which is always parallel to line PQ (see the figure given). Assuming no frictional losses, the kinetic energy of the block when it reaches Q is ($n \times 10$) joules. The value of n is (take acceleration due to gravity = 10 m s^{-2})



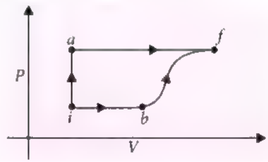
18. A rocket is moving in a gravity free space with a constant acceleration of 2 m s^{-2} along $+x$ direction (see figure). The length of a chamber inside the rocket is 4 m. A ball is thrown from the left end of the chamber in $+x$ direction with a speed of 0.3 m s^{-1} relative to the rocket. At the same time, another ball is thrown in $-x$ direction with a speed of 0.2 m s^{-1} from its right end relative to the rocket. The time in seconds when the two balls hit each other is



19. A horizontal circular platform of radius 0.5 m and mass 0.45 kg is free to rotate about its axis. Two massless spring toy-guns, each carrying a steel ball of mass 0.05 kg are attached to the platform at a distance 0.25 m from the centre on its either sides along its diameter (see figure). Each gun simultaneously fires the balls horizontally and perpendicular to the diameter in opposite directions. After leaving the platform, the balls have horizontal speed of 9 m s^{-1} with respect to the ground. The rotational speed of the platform in rad s^{-1} after the balls leave the platform is



20. A thermodynamic system is taken from an initial state i with internal energy U_i = 100 J to the final state f along two different paths iaf and ibf, as schematically shown in the figure. The work done by the system along the paths af, ib and bf are W_{af} = 200 J, W_{ib} = 50 J and W_{bf} = 100 J respectively. The heat supplied to the system along the path iaf, ib and bf are Q_{iaf}, Q_{ib} and Q_{bf} respectively. If the internal energy of the system in the state b is U_b = 200 J and Q_{iaf} = 500 J, the ratio Q_{bf}/Q_{ib} is



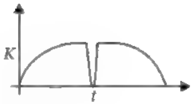
PAPER-2

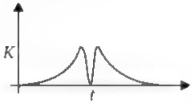
SECTION-1

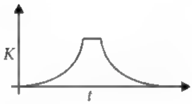
Only One Option Correct Type

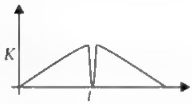
This section contains 10 multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which ONLY ONE are correct.

1. A tennis ball is dropped on a horizontal smooth surface. It bounces back to its original position after hitting the surface. The force on the ball during the collision is proportional to the length of compression of the ball. Which one of the following sketches describes the variation of its kinetic energy K with time t most appropriately? The figures are only illustrative and not to the scale.

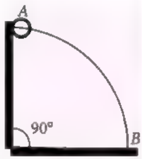
(a) 

(b) 

(c) 

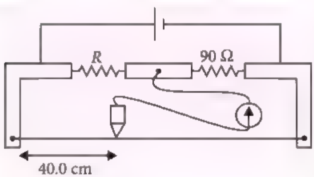
(d) 

2. A wire, which passes through the hole in a small bead, is bent in the form of quarter of a circle. The wire is fixed vertically on ground as shown in the figure. The bead is released from near the top of the wire and it slides along the wire without friction. As the bead moves from A to B, the force it applies on the wire is



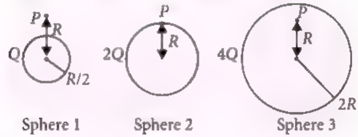
(a) always radially outwards.
(b) always radially inwards.
(c) radially outwards initially and radially inwards later.
(d) radially inwards initially and radially outwards later.

3. During an experiment with a metre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as shown in the figure. The least count of the scale used in the metre bridge is 1 mm. The unknown resistance is



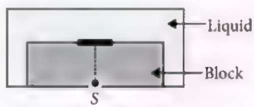
(a) $60 \pm 0.15\ \Omega$ (b) $135 \pm 0.56\ \Omega$
(c) $60 \pm 0.25\ \Omega$ (d) $135 \pm 0.23\ \Omega$

4. Charges Q, $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $R/2$, R and $2R$ respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2 and E_3 respectively, then



(a) $E_1 > E_2 > E_3$ (b) $E_3 > E_1 > E_2$
(c) $E_2 > E_1 > E_3$ (d) $E_3 > E_2 > E_1$

5. A point source S is placed at the bottom of a transparent block of height 10 mm and refractive index 2.72. It is immersed in a lower refractive index liquid as shown in the figure. It is found that the light emerging from the block to the liquid forms a circular bright spot of diameter 11.54 mm on the top of the block. The refractive index of the liquid is



(a) 1.21 (b) 1.30 (c) 1.36 (d) 1.42

6. Parallel rays of light of intensity $I = 912\ \text{W m}^{-2}$ are incident on a spherical black body kept in surroundings of temperature 300 K. Take Stefan-Boltzmann constant $\sigma = 5.7 \times 10^{-8}\ \text{W m}^{-2}\text{K}^{-4}$ and assume that the energy exchange with the surroundings is only through radiation. The final steady state temperature of the black body is close to

(a) 330 K (b) 660 K (c) 990 K (d) 1550 K

7. A metal surface is illuminated by light of two different wavelengths 248 nm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and

u_2, respectively. If the ratio $u_1 : u_2 = 2 : 1$ and $hc = 1240$ eV nm, the work function of the metal is nearly

(a) 3.7 eV (b) 3.2 eV
(c) 2.8 eV (d) 2.5 eV

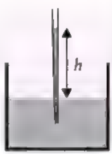
8. If λ_{Cu} is the wavelength of K_α X-ray line of copper (atomic number 29) and λ_{Mo} is the wavelength of the K_α X-ray line of molybdenum (atomic number 42), then the ratio $\lambda_{Cu}/\lambda_{Mo}$ is close to

(a) 1.99 (b) 2.14 (c) 0.50 (d) 0.48

9. A planet of radius $R = \frac{1}{10} \times$(radius of Earth) has the same mass density as Earth. Scientists dig a well of depth $\frac{R}{5}$ on it and lower a wire of the same length and of linear mass density 10^{-3} kg m^{-1} into it. If the wire is not touching anywhere, the force applied at the top of the wire by a person holding it in place is (take the radius of Earth $= 6 \times 10^6$ m and the acceleration due to gravity on Earth is 10 m s^{-2}).

(a) 96 N (b) 108 N
(c) 120 N (d) 150 N

10. A glass capillary tube is of the shape of a truncated cone with an apex angle α so that its two ends have cross sections of different radii. When dipped in water vertically, water rises in it to a height h, where the radius of its cross section is b. If the surface tension of water is S, its density is ρ, and its contact angle with glass is θ, the value of h will be (g is the acceleration due to gravity)



(a) $\frac{2S}{b\rho g}\cos(\theta - \alpha)$

(b) $\frac{2S}{b\rho g}\cos(\theta + \alpha)$

(c) $\frac{2S}{b\rho g}\cos(\theta - \alpha/2)$

(d) $\frac{2S}{b\rho g}\cos(\theta + \alpha/2)$

SECTION-2

Comprehension Type (Only One Option Correct)

This section contains 3 paragraphs, each describing theory, experiments, data etc. Six questions relate to the three paragraphs with two questions on each paragraph. Each question has only one correct answer among the four given options (a), (b), (c) and (d).

Paragraph for questions 11 and 12

In the figure a container is shown to have a movable (without friction) piston on top. The container and the piston are all made of perfectly insulating material allowing no heat transfer between outside and inside the container. The container is divided into two compartments by a rigid partition made of a thermally conducting material that allows slow transfer of heat. The lower compartment of the container is filled with 2 moles of an ideal monoatomic gas at 700 K and the upper compartment is filled with 2 moles of an ideal diatomic gas at 400 K. The heat capacities per mole of an ideal monoatomic gas are $C_V = \frac{3}{2}R$, $C_P = \frac{5}{2}R$ and those for an ideal diatomic gas are $C_V = \frac{5}{2}R$, $C_P = \frac{7}{2}R$.

11. Consider the partition to be rigidly fixed so that it does not move. When equilibrium is achieved, the final temperature of the gases will be

(a) 550 K (b) 525 K (c) 513 K (d) 490 K

12. Now consider the partition to be free to move without friction so that the pressure of gases in both compartments is the same. Then total work done by the gases till the time they achieve equilibrium will be

(a) $250R$ (b) $200R$ (c) $100R$ (d) $-100R$

Paragraph for questions 13 and 14

A spray gun is shown in the figure where a piston pushes air out of a nozzle. A thin tube of uniform cross section is connected to the nozzle. The other end of the tube is in a small liquid container. As the piston pushes air through the nozzle, the liquid from the container rises into the nozzle and

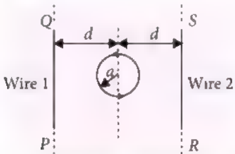
is sprayed out. For the spray gun shown, the radii of the piston and the nozzle are 20 mm and 1 mm respectively. The upper end of the container is open to the atmosphere.

13. If the piston is pushed at a speed of 5 mm s^{-1}, the air comes out of the nozzle with a speed of
(a) 0.1 m s^{-1} (b) 1 m s^{-1}
(c) 2 m s^{-1} (d) 8 m s^{-1}

14. If the density of air is ρ_a and that of the liquid ρ_l, then for a given piston speed the rate (volume per unit time) at which the liquid is sprayed will be proportional to
(a) $\sqrt{\frac{\rho_a}{\rho_l}}$ (b) $\sqrt{\rho_a\rho_l}$
(c) $\sqrt{\frac{\rho_l}{\rho_a}}$ (d) ρ_l

Paragraph for questions 15 and 16

The figure shows a circular loop of radius a with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the centre of the loop is d. The loop and the wires are carrying the same current I. The current in the loop is in the counterclockwise direction if seen from above.



15. When $d \approx a$ but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case
(a) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx a$
(b) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx a$
(c) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx 1.2a$
(d) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx 1.2a$

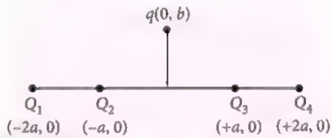
16. Consider $d >> a$, and the loop is rotated about its diameter parallel to the wires by 30° from the position shown in the figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop)
(a) $\frac{\mu_0 I^2 a^2}{d}$ (b) $\frac{\mu_0 I^2 a^2}{2d}$
(c) $\frac{\sqrt{3}\mu_0 I^2 a^2}{d}$ (d) $\frac{\sqrt{3}\mu_0 I^2 a^2}{2d}$

SECTION-3

Matching List Type (Only One Option Correct)

This section contains four questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (a), (b), (c) and (d), out of which one is correct.

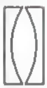
17. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x-axis at $x = -2a$, $-a$, $+a$ and $+2a$ respectively. A positive charge q is placed on the positive y-axis at a distance $b > 0$. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match List I with List II and select the correct answer using the code given below the lists.



	List I		List II
P.	Q_1, Q_2, Q_3, Q_4 all positive	1.	$+x$
Q.	Q_1, Q_2 positive; Q_3, Q_4 negative	2.	$-x$
R.	Q_1, Q_4 positive; Q_2, Q_3 negative	3.	$+y$
S.	Q_1, Q_3 positive; Q_2, Q_4 negative	4.	$-y$

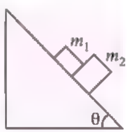
Code :
(a) P - 3, Q - 1, R - 4, S - 2
(b) P - 4, Q - 2, R - 3, S - 1
(c) P - 3, Q - 1, R - 2, S - 4
(d) P - 4, Q - 2, R - 1, S - 3

18. Four combinations of two thin lenses are given in List I. The radius of curvature of all curved surfaces is r and the refractive index of all the lenses is 1.5. Match lens combinations in List I with their focal length in List II and select the correct answer using the code given below the lists.

	List I		List II
P.		1.	$2r$
Q.		2.	$r/2$
R.		3.	$-r$
S.		4.	r

Code :
(a) P - 1, Q - 2, R - 3, S - 4
(b) P - 2, Q - 4, R - 3, S - 1
(c) P - 4, Q - 1, R - 2, S - 3
(d) P - 2, Q - 1, R - 3, S - 4

19. A block of mass $m_1 = 1$ kg, another mass $m_2 = 2$ kg, are placed together (see figure) on an inclined plane with angle of inclination θ. Various values of θ are given in List I. The coefficient of friction between the block m_1 and the plane is always zero. The coefficient of static and dynamic friction between the block m_2 and the plane are equal to $\mu = 0.3$. In List II expressions for the friction on block m_2 are given. Match the correct expression of the friction in List II with the angles given in List I, and choose the correct option. The acceleration due to gravity is denoted by g.



[Useful information : $\tan(5.5°) \approx 0.1$; $\tan(11.5°) \approx 0.2$; $\tan(16.5°) \approx 0.3$]

	List I		List-II
P.	$\theta = 5°$	1.	$m_2 g \sin\theta$
Q.	$\theta = 10°$	2.	$(m_1 + m_2)g \sin\theta$
R.	$\theta = 15°$	3.	$\mu m_2 g \cos\theta$
S.	$\theta = 20°$	4.	$\mu(m_1 + m_2)g \cos\theta$

Code :
(a) P - 1, Q - 1, R - 1, S - 3
(b) P - 2, Q - 2, R - 2, S - 3
(c) P - 2, Q - 2, R - 2, S - 4
(d) P - 2, Q - 2, R - 3, S - 3

20. A person in a lift is holding a water jar, which has a small hole at the lower end of its side. When the lift is at rest, the water jet coming out of the hole hits the floor of the lift at a distance d of 1.2 m from the person. In the following, state of the lift's motion is given in List I and the distance where the water jet hits the floor of the lift is given in List II. Match the statements from List I with those in List II and select the correct answer using the code given below the lists.

	List I		List II
P.	Lift is accelerating vertically up.	1.	$d = 1.2$ m
Q.	Lift is accelerating vertically down with an acceleration less than the gravitational acceleration.	2.	$d > 1.2$ m
R.	Lift is moving vertically up with constant speed.	3.	$d < 1.2$ m
S.	Lift is falling freely.	4.	No water leaks out of the jar

Code :
(a) P - 2, Q - 3, R - 2, S - 4
(b) P - 2, Q - 3, R - 1, S - 4
(c) P - 1, Q - 1, R - 1, S - 4
(d) P - 2, Q - 3, R - 1, S - 1

SOLUTIONS

PAPER-1

1. **(c, d)**

2. **(a, b, c) :** Fringe width, $\beta = \frac{\lambda D}{d}$

where the symbols have their usual meanings.
The fringe widths for λ_1 and λ_2 are

$$\beta_1 = \frac{\lambda_1 D}{d} \text{ and } \beta_2 = \frac{\lambda_2 D}{d}$$

$$\therefore \quad \frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1}; \quad \because \lambda_2 > \lambda_1 \text{ so } \beta_2 > \beta_1$$

Hence, option (a) is correct.
Number of fringes within a distance y on one side of the central maximum is

$$m = \frac{y}{\beta}$$

Since y is same for λ_1 and λ_2

$$\therefore \quad m_1\beta_1 = m_2\beta_2 \text{ or } \frac{m_1}{m_2} = \frac{\beta_2}{\beta_1}$$

$$\because \quad \beta_2 > \beta_1 \text{ so } m_1 > m_2$$

Hence, option (b) is correct.
3rd maxima of λ_2 is located at

$$= \frac{3\lambda_2 D}{d} = 3(600\text{ nm})\frac{D}{d} = (1800\text{ nm})\frac{D}{d}$$

5th minima of λ_1 is located at

$$= (2\times 5 - 1)\frac{\lambda_1 D}{2d} = \frac{9}{2}\frac{\lambda_1 D}{d} = \frac{9}{2}(400\text{ nm})\frac{D}{d}$$

$$= (1800\text{ nm})\frac{D}{d}$$

So, 3rd maximum of λ_2 overlaps with 5th minimum of λ_1.
Hence, option (c) is correct.

Angular separation of fringes, $\theta = \frac{\lambda}{d}$

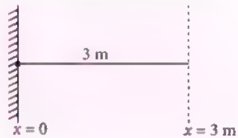
The angular separation of fringes for λ_1 and λ_2 is

$$\theta_1 = \frac{\lambda_1}{d} \text{ and } \theta_2 = \frac{\lambda_2}{d}$$

$$\therefore \quad \frac{\theta_1}{\theta_2} = \frac{\lambda_1}{\lambda_2}$$

As $\lambda_1 < \lambda_2 \; \therefore \; \theta_1 < \theta_2$
Thus the angular separation of fringes for λ_1 is lesser than λ_2. Hence, option (d) is not correct.

3. **(a, c, d) :**



The fixed end is a node while the free end is an antinode.
Therefore, at $x = 0$ is a node and at $x = 3$ m is an antinode.
Possible modes of vibration are

$$L = (2n+1)\frac{\lambda}{4} \text{ where } n = 0, 1, 2, 3, \ldots\ldots$$

$$\text{or} \quad \lambda = \frac{4L}{2n+1} = \frac{12}{2n+1} \quad (\because L = 3\text{ m (Given)})$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{12/(2n+1)} = \frac{(2n+1)\pi}{6}$$

$$\omega = vk = 100(2n+1)\frac{\pi}{6} = \frac{(2n+1)50\pi}{3}$$

For $n = 0$, $k = \frac{\pi}{6}$, $\omega = \frac{50\pi}{3}$

$n = 1$, $k = \frac{\pi}{2}$, $\omega = 50\pi$

$n = 2$, $k = \frac{5\pi}{6}$, $\omega = \frac{250\pi}{3}$

$\vdots \quad \vdots \quad \vdots$

$n = 7$, $k = \frac{5\pi}{2}$, $\omega = 250\pi$

$\vdots \quad \vdots \quad \vdots$

so on
For $n = 0$

$$y(t) = A\sin\frac{\pi x}{6}\cos\frac{50\pi t}{3}$$

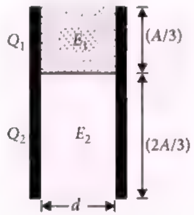
For $n = 2$

$$y(t) = A\sin\frac{5\pi x}{6}\cos\frac{250\pi t}{3}$$

For $n = 7$

$$y(t) = A\sin\frac{5\pi x}{2}\cos 250\pi t$$

4. **(a, d) :** Let A be area of each plate and d is the distance between the plates.



The given capacitor is equivalent to two capacitors in parallel with capacitances

$$C_1 = \frac{K\varepsilon_0(A/3)}{d} = \frac{K\varepsilon_0 A}{3d}$$

$$C_2 = \frac{\varepsilon_0(2A/3)}{d} = \frac{2\varepsilon_0 A}{3d}$$

$$\therefore \quad C = C_1 + C_2$$

$$= \frac{K\varepsilon_0 A}{3d} + \frac{2\varepsilon_0 A}{3d} = \frac{\varepsilon_0 A}{3d}(K+2)$$

$$\therefore \quad \frac{C}{C_1} = \frac{K+2}{K}$$

Hence, option (d) is correct.

Let V be potential difference between the plates. Then

$$E_1 = \frac{V}{d} \text{ and } E_2 = \frac{V}{d}$$

$$\therefore \quad \frac{E_1}{E_2} = 1$$

Hence, option (a) is correct and option (b) is incorrect.

$$Q_1 = C_1 V = \frac{K\varepsilon_0 A}{3d}V \text{ and } Q_2 = C_2 V = \frac{2\varepsilon_0 A}{3d}V$$

$$\therefore \quad \frac{Q_1}{Q_2} = \frac{K}{2}$$

Hence, option (c) is incorrect.

5. **(c) :** $E_1(r) = \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{r^2}$

$$E_2(r) = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$E_3(r) = \frac{\sigma}{2\varepsilon_0}$$

At $r = r_0$,

$$E_1(r_0) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_0^2}$$

$$E_2(r_0) = \frac{\lambda}{2\pi\varepsilon_0 r_0}$$

$$E_3(r_0) = \frac{\sigma}{2\varepsilon_0}$$

As $E_1(r_0) = E_2(r_0) = E_3(r_0)$ (Given)

$$\therefore \quad \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_0^2} = \frac{\lambda}{2\pi\varepsilon_0 r_0} = \frac{\sigma}{2\varepsilon_0}$$

Then

$$\frac{1}{4\pi\varepsilon_0}\frac{Q}{r_0^2} = \frac{\sigma}{2\varepsilon_0}$$

or $Q = 2\sigma\pi r_0^2$

Hence, option (a) is incorrect.

Now, $\dfrac{\lambda}{2\pi\varepsilon_0 r_0} = \dfrac{\sigma}{2\varepsilon_0}$

or $\quad r_0 = \dfrac{\lambda}{\pi\sigma}$

Hence, option (b) is incorrect.

At $r = r_0/2$,

$$E_1(r_0/2) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{(r_0/2)^2} = \frac{4}{4\pi\varepsilon_0}\frac{Q}{r_0^2} = 4E_1(r_0)$$

or $E_1(r_0) = \dfrac{1}{4}E_1(r_0/2)$

$$E_2(r_0/2) = \frac{\lambda}{2\pi\varepsilon_0(r_0/2)} = \frac{2\lambda}{2\pi\varepsilon_0 r_0} = 2E_2(r_0)$$

or $E_2(r_0) = \dfrac{1}{2}E_2(r_0/2)$

$$\because \quad E_1(r_0) = E_2(r_0)$$

$$\therefore \quad \frac{1}{4}E_1(r_0/2) = \frac{1}{2}E_2(r_0/2)$$

or $E_1(r_0/2) = 2E_2(r_0/2)$

Hence, option (c) is correct.

$$E_3(r_0/2) = \frac{\sigma}{2\varepsilon_0} = E_3(r_0)$$

$\because \quad E_2(r_0) = E_3(r_0)$

$\therefore \quad \frac{1}{2}E_2(r_0/2) = E_3(r_0/2)$

or $\quad E_2(r_0/2) = 2E_3(r_0/2)$

Hence, option (d) is incorrect.

6. **(d):** For minimum height,

$\frac{\lambda}{4} = l$ or $\lambda = 4l$

As $v = \upsilon\lambda = 4\upsilon l$ and $\frac{\Delta v}{v} = \frac{\Delta l}{l}$

Here, $\upsilon = 244\ \text{s}^{-1}$, $l = (0.350 \pm 0.005)$ m

$\therefore \quad v = 4\upsilon l = 4 \times 244 \times 0.350 = 341.6\ \text{m s}^{-1}$

and $\Delta v = v \times \frac{\Delta l}{l} = 341.6 \times \frac{0.005}{0.350} = 4.88\ \text{m s}^{-1}$

Thus, the v lies between 336.7 m s^{-1} to 346.5 m s^{-1}.

Now, $v = \sqrt{\frac{\gamma RT}{M \times 10^{-3}}}$, where M is the molecular mass in grams.

For monatomic gas, $\gamma = 1.67$

$$v = \sqrt{\frac{1.67RT}{M \times 10^{-3}}} = \sqrt{\frac{1.67 \times 100 \times RT \times 10}{M}}$$

$$= \sqrt{167RT} \times \sqrt{\frac{10}{M}} = 640 \times \sqrt{\frac{10}{M}}$$

For diatomic gas, $\gamma = 1.4$

$$v = \sqrt{\frac{1.4RT}{M \times 10^{-3}}} = \sqrt{\frac{1.4 \times 100 \times RT \times 10}{M}}$$

$$= \sqrt{140RT} \times \sqrt{\frac{10}{M}} = 590 \times \sqrt{\frac{10}{M}}$$

Gas	Nature of gas	M	$\sqrt{\frac{10}{M}}$	v (m s^{-1})
Neon (Ne)	Monatomic	20	$\frac{7}{10}$	448
Nitrogen (N_2)	Diatomic	28	$\frac{3}{5}$	354
Oxygen (O_2)	Diatomic	32	$\frac{9}{16}$	331.8
Argon (Ar)	Monatomic	36	$\frac{17}{32}$	340

$\therefore$ Only possible answer is argon.

7. **(b, d) :** In a given heater,

$$R = \frac{\rho L}{\pi(d/2)^2} = \frac{4\rho L}{\pi d^2}$$

$$H = \frac{V^2}{R}t$$

In a new heater,

$$R_1 = \frac{\rho L}{\pi(2d/2)^2} = \frac{\rho L}{\pi d^2}$$

and $R_2 = \frac{\rho L}{\pi(2d/2)^2} = \frac{\rho L}{\pi d^2}$

$\therefore \quad R_1 = R_2 = \frac{R}{4}$

If wires are connected in series, their equivalent resistance is

$$R_s = R_1 + R_2 = \frac{R}{4} + \frac{R}{4} = \frac{R}{2}$$

Then, $H_s = \frac{V^2}{R_s}t_s = \frac{V^2}{(R/2)}t_s = \frac{2V^2}{R}t_s$

As $H = H_s$

$\therefore \quad \frac{V^2}{R}t = \frac{2V^2}{R}t_s$ or $t_s = \frac{t}{2} = \frac{4}{2} = 2$ min

If the wires are connected in parallel, their equivalent resistance is

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{(R/4)} + \frac{1}{(R/4)} = \frac{4}{R} + \frac{4}{R} = \frac{8}{R}$$

$$R_p = \frac{R}{8}$$

Then, $H_p = \frac{V^2}{R_p}t_p = \frac{V^2}{(R/8)}t_p = \frac{8V^2}{R}t_p$

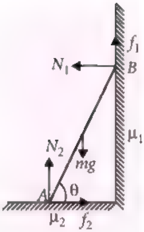
As $H = H_p$

$\therefore \quad \frac{V^2}{R}t = \frac{8V^2}{R}t_p$

or $\quad t_p = \frac{t}{8} = \frac{4}{8} = 0.5$ min

8. **(c, d) :** The various forces acting on the ladder are as shown in the figure.

Let L be the length of the ladder.



Since the ladder is about to slip so both friction will be limiting.

$\therefore\ f_1 = \mu_1 N_1$

and $f_2 = \mu_2 N_2$

In options (a) and (d), $\mu_1 = 0$

$\therefore\ f_1 = 0$

For rotational equilibrium

Taking the moments about A,

$$N_1 L\sin\theta - mg\frac{L}{2}\cos\theta = 0$$

$$N_1\sin\theta = \frac{mg}{2}\cos\theta \text{ or } N_1\tan\theta = \frac{mg}{2}$$

Hence, option (d) is correct.

For translational equilibrium

Taking the forces in horizontal and vertical direction,

$f_2 - N_1 = 0$ or $N_1 = f_2 = \mu_2 N_2$ and

$N_2 - mg = 0$ or $N_2 = mg$

Hence, option (a) is not correct.

In option (b), $\mu_2 = 0$

There is no force to balance N_1, so ladder can't remain in equilibrium.

In option (c), $\mu_1 \neq 0$, $\mu_2 \neq 0$

For translational equilibrium

Taking the forces in horizontal and vertical directions,

$f_2 - N_1 = 0$ ...(i)

and $N_2 + f_1 - mg = 0$ ...(ii)

From eqn. (i),

$N_1 = f_2 = \mu_2 N_2$ ...(iii)

From eqn. (ii), $N_2 + f_1 = mg$

$N_2 + \mu_1 N_1 = mg$ ...(iv)

$N_2 + \mu_1\mu_2 N_2 = mg$ (Using (iii))

$N_2(1 + \mu_1\mu_2) = mg$

$$N_2 = \frac{mg}{1+\mu_1\mu_2}$$

Hence, option (c) is correct.

9. **(a, c) :** $\frac{1}{f_{\text{film}}} = (n_1 - 1)\left(\frac{1}{R} - \frac{1}{R}\right) = 0$

$\therefore\ f_{\text{film}} = \infty$

Therefore, there is no effect of presence of film.

Thus, we can find the answer just by considering air-glass interface.

From air to glass

Using refraction at a spherical surface from rarer to denser medium

$$\frac{n_2}{v} - \frac{1}{u} = \frac{n_2 - 1}{R}$$

$$\frac{1.5}{v} - \frac{1}{\infty} = \frac{1.5-1}{R}$$

$$\frac{1.5}{v} = \frac{0.5}{R} \quad\text{or}\quad v = \frac{1.5}{0.5}R = 3R$$

$\therefore\ f_1 = 3R$

From glass to air

Using refraction at a spherical surface from denser to rarer medium

$$\frac{1}{v} - \frac{n_2}{u} = \frac{1-n_2}{-R}$$

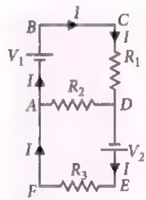
$$\frac{1}{v} - \frac{1.5}{\infty} = \frac{1-1.5}{-R}$$

$$\frac{1}{v} = \frac{0.5}{R} \quad\text{or}\quad v = \frac{R}{0.5} = 2R$$

$\therefore\ f_2 = 2R$

10. **(a, b, d) :** No current is flowing in R_2.

Applying Kirchhoff's second law for closed loop $ABCDEFA$, we get



$V_1 - IR_1 + V_2 - IR_3 = 0$

$$I = \frac{V_1 + V_2}{R_1 + R_3} \quad ...(i)$$

Again applying Kirchhoff's second law for closed loop $ABCDA$, we get

$V_1 - IR_1 = 0$

$$I = \frac{V_1}{R_1} \quad ...(ii)$$

Equating (i) and (ii), we get

$$\frac{V_1}{R_1} = \frac{V_1 + V_2}{R_1 + R_3}$$

$V_1R_1 + V_1R_3 = V_1R_1 + V_2R_1$

$V_1R_3 = V_2R_1$

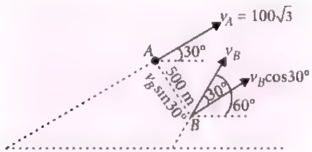
$$\frac{V_1}{V_2} = \frac{R_1}{R_3}$$

Hence, current in R_2 will be zero if

$$\frac{V_1}{V_2} = \frac{R_1}{R_3}$$

This condition is satisfied by options (a), (b) and (d).

11. (5) :



The relative velocity of B with respect to A is perpendicular to the line of motion of A.

$\therefore \quad v_B\cos30° = v_A$

$$v_B = \frac{v_A}{\cos 30°} = \frac{100\sqrt{3}}{\sqrt{3}/2} = 200 \text{ m s}^{-1}$$

$$\therefore \quad t_0 = \frac{500}{v_B \sin 30°} = \frac{500}{200 \times \frac{1}{2}} = 5 \text{ s}$$

12. (4) : Young's Modulus, $Y = \dfrac{MgL}{Al}$

where,

M = Load applied

L = Original length of the wire

A = Area of cross-section of the wire

l = Extension produced in the wire

As the experiment measures only extension in the wire.

$$\therefore \quad \frac{\Delta Y}{Y} = \frac{\Delta l}{l}$$

The maximum percentage error in Y is

$$\frac{\Delta Y}{Y} \times 100 = \frac{\Delta l}{l} \times 100$$

Here, $\Delta l = 1 \times 10^{-5}$ m

$l = 25 \times 10^{-5}$ m

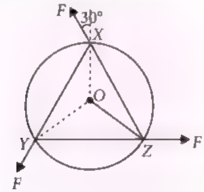
$$\therefore \quad \frac{\Delta Y}{Y} \times 100 = \frac{1 \times 10^{-5}}{25 \times 10^{-5}} \times 100 = 4\%$$

13. (2) : Here,

Mass of the disc, $M = 1.5$ kg

Radius of the disc, $R = 0.5$ m

Also, $F = 0.5$ N



Net torque about the point O, which is produced by the given forces is

$\tau = 3FR\sin30°$

$$= 3 \times 0.5 \times 0.5 \times \frac{1}{2} = 3 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{3}{8} \text{ N m}$$

Moment of inertia of the disc,

$$I = \frac{1}{2}MR^2$$

$$= \frac{1}{2} \times 1.5 \times (0.5)^2 = \frac{1}{2} \times \frac{15}{10} \times \frac{1}{2} \times \frac{1}{2}$$

$$= \frac{3}{16} \text{ kg m}^2$$

As $\tau = I\alpha$

$\therefore$ Angular acceleration

$$\alpha = \frac{\tau}{I} = \frac{\frac{3}{8} \text{ N m}}{\frac{3}{16} \text{ kg m}^2} = 2 \text{ rad s}^{-2}$$

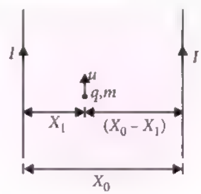
Let ω be angular speed of the disc after 1 s.

$\therefore \quad \omega = \omega_0 + \alpha t = 0 + 2 \times 1 = 2 \text{ rad s}^{-1}$

($\because$ $\omega_0 = 0$, as the disc starts from rest)

14. (3) : Case-1

When the currents are in the same direction



$$B_1 = \frac{\mu_0 I}{2\pi X_1} - \frac{\mu_0 I}{2\pi(X_0 - X_1)}$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{1}{X_1} - \frac{1}{(X_0 - X_1)}\right]$$

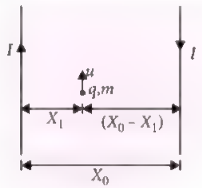
$$= \frac{\mu_0 I}{2\pi}\left[\frac{X_0 - X_1 - X_1}{X_1(X_0 - X_1)}\right]$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{X_0 - 2X_1}{X_1(X_0 - X_1)}\right]$$

$$R_1 = \frac{mu}{qB_1}$$

Case-2

When the currents are in the opposite direction



$$B_2 = \frac{\mu_0 I}{2\pi X_1} + \frac{\mu_0 I}{2\pi(X_0 - X_1)}$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{1}{X_1} + \frac{1}{(X_0 - X_1)}\right]$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{X_0 - X_1 + X_1}{X_1(X_0 - X_1)}\right]$$

$$B_2 = \frac{\mu_0 I}{2\pi}\left[\frac{X_0}{X_1(X_0 - X_1)}\right]$$

$$R_2 = \frac{mu}{qB_2}$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{B_2}{B_1} = \frac{X_0}{X_0 - 2X_1} = \frac{\frac{X_0}{X_1}}{\frac{X_0}{X_1} - 2} = \frac{3}{3-2} = 3$$

15. (3) : Let $d \propto \rho^x S^y f^z$

or $d = k\rho^x S^y f^z$

where k is a dimensionless constant and x, y and z are the exponents.

Writing dimensions on both sides, we get

$[M^0LT^0] = [ML^{-3}T^0]^x[ML^0T^{-3}]^y[M^0L^0T^{-1}]^z$

$[M^0LT^0] = [M^{x+y}L^{-3x}T^{-3y-z}]$

Applying the principle of homogeneity of dimensions, we get

$x + y = 0$ ...(i)

$-3x = 1$ ...(ii)

$-3y - z = 0$ ...(iii)

Solving eqns. (i), (ii) and (iii), we get

$$x = -\frac{1}{3},\ y = \frac{1}{3},\ z = -1$$

As $d \propto S^{1/3}$

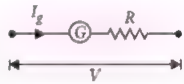
$\therefore \quad n = 3$

16. (5) : Here,

Current for full scale deflection, $I_g = 0.006$ A

Let G be resistance of the galvanometer.

To convert the given galvanometer into a voltmeter of range 0 – 30 V *i.e.* $V = 30$ V, a resistance R is connected in series with it such that



$V = I_g(G + R)$

$30 = 0.006(G + 4990)$

$$\frac{30}{0.006} = (G + 4990)$$

$$\frac{30 \times 1000}{6} = G + 4990$$

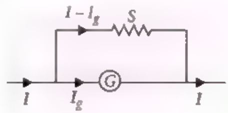
$5000 = G + 4990$

$G = 10\ \Omega$

To convert the given galvanometer into ammeter of range of 0 – 1.5 A i.e. $I = 1.5$ A a resistance of value S is connected in parallel with it such that

$(I - I_g)S = I_gG$

$$(1.5 - 0.006) \times \frac{2n}{249} = 0.006 \times 10$$



$$\frac{2n}{249} = \frac{0.06}{1.494}$$

$$2n = \frac{0.06 \times 249}{1.494} = 10$$

or $n = 5$

17. (5) : Work done by the gravitational force is

$W_g = mgh\cos 180°$

$= -mgh = -1 \times 10 \times 4 = -40$ J

Work done by the applied force F

$W_F = Fd\cos 0° = Fd = 18 \times 5 = 90$ J

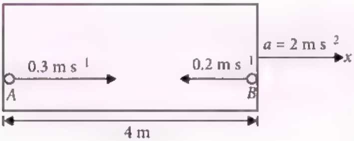
According to work-energy theorem

$\Delta K = W_g + W_F$

$\Delta K = -40 \text{ J} + 90 \text{ J} = 50 \text{ J} = (5 \times 10)\text{J}$

$\therefore \quad n = 5$

18. (2 or 8) :



Consider the motion of two balls with respect to rocket.

Distance travelled by ball A from left end of the chamber is

$$= \frac{u^2}{2a} = \frac{(0.3)^2}{2 \times 2} = \frac{0.09}{4} \approx 0.02 \text{ m}$$

So collision of two balls will take place very near to left end of the chamber.

For ball B

$$S = ut + \frac{1}{2}at^2$$

$$-4 = -0.2 \times t - \frac{1}{2} \times 2 \times t^2$$

$$t^2 + 0.2t - 4 = 0$$

$$t = \frac{-0.2 \pm \sqrt{(0.2)^2 - 4(1)(-4)}}{2}$$

$$= \frac{-0.2 \pm \sqrt{0.04 + 16}}{2}$$

$t = 1.9$ s, -2.1 s

Since t can't be negative

$\therefore \quad t = 1.9$ s

Nearest integer is 2 s.

Also, from

$$S = ut + \frac{1}{2}at^2$$

$$S_A = 0.3t + \frac{1}{2}(-2)t^2 = 0.3t - t^2$$

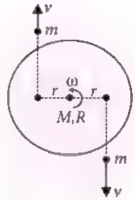
$$S_B = 0.2t + \frac{1}{2}(2)t^2 = 0.2t + t^2$$

$\because \quad S_A + S_B = 4$

$\Rightarrow \quad 0.5\,t = 4$

or $\quad t = 8$ s

19. (4) : According to law of conservation of angular momentum



$L_i = L_f$

$0 = mvr + mvr - I\omega$

$I\omega = 2mvr$

$$\omega = \frac{2mvr}{I} = \frac{2mvr}{\frac{MR^2}{2}}$$

$\left(\because \text{ For circular platform } I = \frac{MR^2}{2}\right)$

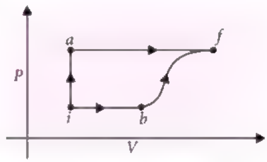
$$\omega = \frac{4mvr}{MR^2}$$

Here, $m = 0.05$ kg, $r = 0.25$ m, $v = 9$ m s^{-1}

$M = 0.45$ kg, $R = 0.5$ m

$$\therefore \quad \omega = \frac{4 \times 0.05 \times 9 \times 0.25}{0.45 \times (0.5)^2} = 4 \text{ rad s}^{-1}$$

20. (2) :



Along the path ia, V = constant

$\therefore \quad W_{ia} = 0$

Along the path iaf,

$W_{iaf} = W_{ia} + W_{af} = 0 \text{ J} + 200 \text{ J} = 200 \text{ J}$

$Q_{iaf} = 500$ J

$U_{iaf} = Q_{iaf} - W_{iaf} = 500 \text{ J} - 200 \text{ J} = 300 \text{ J}$

$\therefore \quad U_f - U_i = 300$ J

$U_f = 300 \text{ J} + U_i = 300 \text{ J} + 100 \text{ J} = 400 \text{ J}$

Along the path ib

$U_{ib} = U_b - U_i = 200 \text{ J} - 100 \text{ J} = 100 \text{ J}$

$W_{ib} = 50$ J

$\therefore \quad Q_{ib} = U_{ib} + W_{ib} = 100 \text{ J} + 50 \text{ J} = 150 \text{ J}$

Along the path bf,

$U_{bf} = U_f - U_b = 400 \text{ J} - 200 \text{ J} = 200 \text{ J}$

$W_{bf} = 100$ J

$\therefore \quad Q_{bf} = U_{bf} + W_{bf} = 200 \text{ J} + 100 \text{ J} = 300 \text{ J}$

The required ratio is

$$\frac{Q_{bf}}{Q_{ib}} = \frac{300 \text{ J}}{150 \text{ J}} = 2$$

PAPER-2

1. **(b)** : As tennis ball is dropped, so its initial velocity, $u = 0$

Suppose its velocity at any time $t = v$

Acceleration due to gravity $= g$

$\therefore \quad v = u + gt$

$\Rightarrow \quad v = gt \qquad \text{... (i)}$

We know, kinetic energy,

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m(g^2t^2) \qquad \text{[Using eqn. (i)]}$$

$$\Rightarrow \quad K = \frac{1}{2}mg^2t^2$$

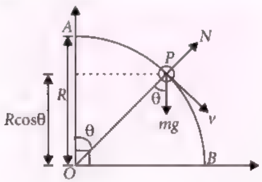
$\Rightarrow \quad K \propto t^2 \qquad$ (As m and g are constant)

This shows that relation between kinetic energy of tennis ball K and time t is parabolic.

During the collision, velocity of the ball falls sharply to zero as it is compressed and regains maximum velocity in the same short time interval.

This relation is best illustrated by the option (b).

2. **(d)** : Suppose bead is at point P at any time t as shown in figure.



Where m = mass of bead, N = normal on the bead by wire, v = speed of the bead and R = radius of quarter circle (= $OA = OP = OB$)

There is no fricton between bead and wire. So, applying energy conservation principle,

(Mechanical energy)$_A$ = (Mechanical energy)$_P$

$$\Rightarrow \quad mgR + 0 = mgR\cos\theta + \frac{1}{2}mv^2$$

$$\Rightarrow \quad mgR(1 - \cos\theta) = \frac{1}{2}mv^2 \qquad \text{... (i)}$$

Using Newton's second law of motion at point P,

$$mg\cos\theta - N = \frac{mv^2}{R}$$

$$\Rightarrow \quad N = mg\cos\theta - \frac{mv^2}{R}$$

$$= mg\cos\theta - 2mg(1 - \cos\theta)$$

[Using eqn. (i)]

$\Rightarrow \quad N = mg(3\cos\theta - 2)$

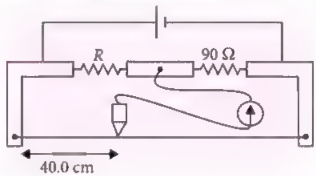
When $3\cos\theta > 2$, direction of N will be same as shown in figure, *i.e.*, radially outward.

When $3\cos\theta < 2$, direction of N will be radially inward.

Now, normal on the bead is opposite to the force applied on the wire by the bead, following Newton's third law.

Therefore, the force applied on the bead by the wire is radially inwards initially and radially outwards later, as it moves from A to B.

3. **(c):**



When a metre bridge is balanced, then

$$\frac{R_1}{x} = \frac{R_2}{(100 - x)} \qquad \text{...(i)}$$

From figure,

$R_1 = R$, $R_2 = 90\ \Omega$, $x = 40$ cm

$$\text{Then,} \quad \frac{R}{40} = \frac{90}{(100 - 40)} = \frac{90}{60}$$

$\Rightarrow \quad R = 60\ \Omega$

Now, for ΔR taking natural log on both sides of eqn. (i),

$\ln R_1 = \ln R_2 + \ln x - \ln(100 - x)$

or $\quad \ln R = \ln x - \ln(100 - x) + \ln(90)$

On differentiating,

$$\frac{\Delta R}{R} = \frac{\Delta x}{x} - \frac{\Delta(100 - x)}{(100 - x)}$$

$$\Rightarrow \quad \frac{\Delta R}{R} = \frac{\Delta x}{x} + \frac{\Delta x}{(100 - x)}$$

$$\Rightarrow \quad \Delta R = \left(\frac{0.1}{40} + \frac{0.1}{60}\right) \times 60 = \frac{0.5}{120} \times 60 = 0.25\ \Omega$$

$\therefore \quad$ Required value of $R = (60 \pm 0.25)\ \Omega$

Contd. on page no. 86

CBSE BOARD 2015

CHAPTERWISE PRACTICE PAPER

SERIES-2

Current Electricity

GENERAL INSTRUCTIONS

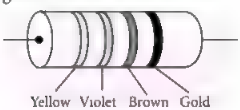
(i) All questions are compulsory.
(ii) There are 30 questions in total. Questions Nos. 1 to 8 are very short answer type questions and carry one mark each.
(iii) Questions Nos. 9 to 18 carry two marks each. Questions Nos. 19 to 27 carry three marks each and questions Nos. 28 to 30 carry five marks each.
(iv) One of the questions carrying three marks weightage is value based question.
(v) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each weightage. You have to attempt only one of the choices in such questions.
(vi) Use of calculators is not permitted. However, you may use log tables if necessary.

1. Is emf a scalar or vector quantity?

2. The coil of a heater is cut into two equal halves and only one of them is used in heater. What is the ratio of the heat produced by this half coil to that by the original coil?

3. A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for r in terms of ε, V and R.

4. A carbon resistor has coloured stripes as shown in figure. What is its resistance?



5. If the electron drift is so small, how can we obtain large amount of current in a conductor?

6. State the condition in which terminal voltage across a secondary cell is equal to its emf.

7. When is a Wheatstone's bridge most sensitive?

8. The resistance of a tungsten filament at 150°C is 133 Ω. What will be its resistance at 500°C? The temperature coefficient of resistance of tungsten is $0.0045°C^{-1}$ at 0°C.

9. The number density of free electrons in a copper conductor is estimated as $8.5 \times 10^{28}\ m^{-3}$. How long does an electron take to drift from one end of a wire 3 m long to its other end? The area of cross-section of the wire is $2 \times 10^{-6}\ m^2$ and it is carrying a current of 3 A.

10. A heater joined in series with a 50 W bulb is connected to the mains. If the 50 W bulb is replaced by a 100 W bulb, then will the heater now give more heat, less heat or same heat? Why?

11. Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1 mm. Conductor B is a hollow tube of outer diameter 2 mm and inner diameter 1 mm. Find the ratio of resistance R_A to R_B.

12. (a) Three resistors 2 Ω, 4 Ω and 5 Ω are combined in parallel. What is the total resistance of the combination?
(b) If the combination is connected to a battery of emf 20 V and negligible internal resistance, determine the current through each resistance, and the total current drawn from the battery.

13. Explain how electron mobility changes for a good conductor when
(i) the temperature of the conductor is decreased at constant potential difference and
(ii) applied potential difference is doubled at constant temperature.

14. Two heating elements of resistance R_1 and R_2 when operated at a constant supply of voltage V, consume powers P_1 and P_2 respectively. Deduce the expression for the power of their combination when they are in turn, connected in (a) series and (b) parallel across the same voltage supply.

15. Write the mathematical relation between mobility and drift velocity of charge carriers in a conductor. Name the mobile charge carriers responsible for conduction of electric current in (i) an electrolyte (ii) an ionised gas.

16. Explain why an electric bulb becomes dim when an electric heater in parallel circuit is made on. Why dimness decreases after some time?

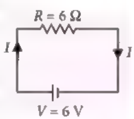
OR

A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor R.
(i) If the current in the circuit is 0.5 A, calculate the value of R.
(ii) What is the terminal voltage of the battery?

17. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63 cm, what is the emf of the second cell?

18. A wire is drawn into double its length and half its original cross-section. What will be increase in its (i) resistance and (ii) resistivity?

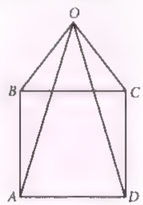
19. (a) Consider the circuit in the given figure. How much energy is absorbed by electrons from the initial state of no current (ignore thermal motion) to the state of drift velocity?



(b) Electrons give up energy at the rate of RI^2 per second to the thermal energy. What time scale would one associate with energy in problem (a)?
(Given n = no of electrons/volume = $10^{29}\,m^{-3}$, length of wire = 10 cm, cross-sectional area, A = 1 mm^2).

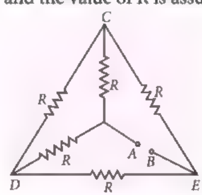
20. Rahul is aware of the fact that rubber and wood are insulators, so there are no free electrons or current carriers in them. Therefore, current can not flow through them. On the other hand human body and earth are good conductors. A current of 10 mA or more passing through human body can be fatal. A current will flow only if the circuit is complete.
Read the above passage and answer the following questions:
(i) How can Rahul repair on live line wires?
(ii) Why is a current of 10 mA or more passing through human body fatal?
(iii) What is the practical utility of this study?

21. Eight identical resistances r each are connected along edges of a pyramid having square base $ABCD$ as shown in figure. Calculate the equivalent resistance between A and D.

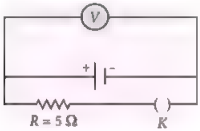


OR

(i) Calculate the equivalent resistance of the given electrical network between points A and B.
(ii) Also calculate the current through CD and ACB, if a 10 V dc source is connected between A and B, and the value of R is assumed as 2 Ω.



22. Write any two factors on which internal resistance of a cell depends. The reading on a high resistance voltmeter, when a cell is connected across it, is 2.2 V. When the terminals of the cell are also connected to a resistance of 5 Ω as shown in the circuit, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell.

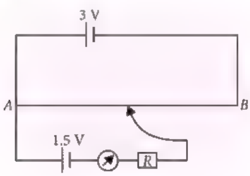


23. Two wires made of tinned copper having identical cross-section (= 10^{-6} m^2) and lengths 10 cm and 15 cm are to be used as fuses. Show that the fuses will melt at the same value of current in each case.

24. A battery of 6 lead accumulators, each of emf 2.0 V and internal resistance 0.25 Ω, is charged by a 230 V dc mains. To limit the charging current, a series resistance of 53 Ω is used in the charging circuit. What is (a) the power supplied by the mains and (b) the power dissipated as heat?

25. Define resistivity of a conductor. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. How does one explain such a behaviour, using the mathematical expression of the resistivity of a material.

26. A potentiometer wire of length 1 m is connected to a driver cell of emf 3 V as shown in figure. When a cell of emf 1.5 V is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell and using a cell of unknown emf, the balance point shifts to 80 cm.

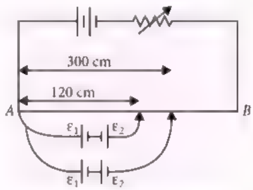


(i) Calculate unknown emf of the cell.

(ii) Explain with reason, whether the circuit works, if the driver cell is replaced with a cell of emf 1 V.

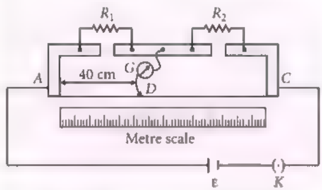
(iii) Does the high resistance R, used in the secondary circuit affect the balance point?

27. In the figure a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end A. Find (a) $\varepsilon_1/\varepsilon_2$ and (b) position of null point for the cell ε_1. How is the sensitivity of a potentiometer increased?



28. (a) State Kirchhoff's rules for an electric network. Using Kirchhoff's rules, obtain the balance condition in terms of the resistances of four arms of Wheastone bridge.

(b) In the meter bridge experimental set up, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of the meter bridge wire.



If a resistance of 10 Ω is connected in series with R_1, null point is obtained at AD = 60 cm. Find the values of R_1 and R_2.

OR

Discuss the variation of resistivity with temperature in case of (i) metals (ii) alloys and (iii) semiconductors.

29. Find the conditions for maximum current in the external resistor R when number of cells each of emf ε and internal resistance r are connected (i) in series (ii) in parallel and (iii) in mixed grouping.

OR

Discuss the movement of free electrons in a conductor when electric field is applied. Hence, derive expressions for drift velocity, current, conductivity of medium and mobility of electrons.

30. Three cells are connected in parallel with their like poles connected together with wires of negligible resistance. If the emfs of the cells are 2 V, 1 V and 4 V respectively and their internal resistances are 4 Ω, 3 Ω and 2 Ω respectively, find the current through each cell.

OR

(a) State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs.
(b) Write two possible causes for one sided deflection in a potentiometer experiment.

SOLUTIONS

1. Emf is a scalar quantity.

2. Original heat produced, $H = \dfrac{V^2 t}{R}$

The resistance of half part of a coil, $R' = R/2$

$\therefore$ Heat produced, $H' = \dfrac{V^2 t}{R'} = \dfrac{V^2 t}{R/2}$

$\therefore \dfrac{H'}{H} = 2$

3. Here, $\varepsilon = I(R + r)$ and $V = IR$

$\therefore \dfrac{\varepsilon}{V} = \dfrac{R+r}{R} = 1 + \dfrac{r}{R}$

or $\dfrac{r}{R} = \left(\dfrac{\varepsilon}{V} - 1\right)$ or $r = \left(\dfrac{\varepsilon}{V} - 1\right) R$

4. Here, number for yellow colour = 4

number for violet colour = 7

number for brown colour = 1

Thus, value of the resistance $= 47 \times 10^1\ \Omega$

$= 470\ \Omega$

The fourth coloured stripe in gold denotes a tolerance of ±5%.

$\therefore$ Resistance of the given resistor

$= 470\ \Omega \pm 5\%$

5. The number density of free electrons in a conductor is very large, so even if the electron drift is so small, we obtain a large amount of current in a conductor.

6. In an open circuit, terminal voltage across a secondary cell is equal to its emf.

7. The Wheatstone's bridge is most sensitive when all the four resistances of bridge are equal.

8. Here, $R_{150} = 133\ \Omega$, $\alpha = 0.0045°C^{-1}$

We know, $R_t = R_0(1 + \alpha t)$

$\therefore R_{150} = R_0(1 + \alpha \times 150)$

or $133 = R_0(1 + 0.0045 \times 150)$ ...(i)

And $R_{500} = R_0(1 + \alpha \times 500)$

or $R_{500} = R_0(1 + 0.0045 \times 500)$ ...(ii)

Dividing (ii) by (i) we get

$$\frac{R_{500}}{133} = \frac{1+0.0045\times 500}{1+0.0045\times 150} = \frac{3.25}{1.675}$$

or $R_{500} = \dfrac{3.25}{1.675} \times 133 = 258\ \Omega$

9. Here, $n = 8.5 \times 10^{28}\ m^{-3}$, $l = 3$ m

$A = 2 \times 10^{-6}\ m^2$, $I = 3$ A

As, $I = nAev_d$ $\therefore v_d = \dfrac{I}{nAe}$,

Now, $t = \dfrac{l}{v_d} = \dfrac{lnAe}{I}$

$$= \frac{3\times 8.5\times 10^{28}\times 2\times 10^{-6}\times 1.6\times 10^{-19}}{3}$$

$= 2.72 \times 10^4$ s

10. Resistance of 100 W bulb is less than that of 50 W bulb. When 50 W bulb is replaced by 100 W bulb, connected in series with heater, the resistance of circuit decreases and hence current increases. As $H \propto I^2$, therefore the heater will now give more heat.

11. For a solid wire of resistance R_A,

$l_1 = l, \rho_1 = \rho, D_1 = 1$ mm, $A_1 = \frac{\pi D_1^2}{4}$

$= \frac{\pi(1)^2}{4}$ mm^2

$$R_A = \frac{\rho_1 l_1}{A_1} = \frac{\rho l}{\pi(1)^2/4} = \frac{4\rho l}{\pi}$$

For hollow tube of resistance R_B,

$l_2 = l, \rho_2 = \rho, D_2 = 2$ mm, $D_1 = 1$ mm

$$A_2 = \frac{\pi}{4}(D_2^2 - D_1^2) = \frac{3\pi}{4}\text{ mm}^2$$

$$R_B = \frac{\rho_2 l_2}{A_2} = \frac{\rho l}{(3\pi/4)} = \frac{4\rho l}{3\pi} \quad \text{or} \quad \frac{R_A}{R_B} = 3$$

12. (a) Here, $R_1 = 2\ \Omega, R_2 = 4\ \Omega, R_3 = 5\ \Omega$,

In parallel combination, total resistance R_p is given by

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20}$$

$$\Rightarrow R_p = \frac{20}{19}\ \Omega$$

(b) Current through $R_1 = \frac{\varepsilon}{R_1} = \frac{20}{2} = 10$ A,

Current through $R_2 = \frac{20}{4} = 5$ A

Current through $R_3 = \frac{20}{5} = 4$ A

Total current $= \frac{20}{\left(\frac{20}{19}\right)} = 19$ A

13. Electron mobility, $\mu_e = \frac{e\tau_e}{m_e}$

(i) When the temperature of the conductor decreases, relaxation time (τ_e) increases and consequently μ_e increases.

(ii) μ_e does not depend on potential difference

14. Here, $P_1 = \frac{V^2}{R_1}$ and $P_2 = \frac{V^2}{R_2}$

(a) For series combination, $P_s = \frac{V^2}{R_s} = \frac{V^2}{R_1 + R_2}$

$$\text{or} \quad P_s = \frac{V^2}{\frac{V^2}{P_1} + \frac{V^2}{P_2}} = \frac{1}{\frac{1}{P_1} + \frac{1}{P_2}} = \frac{P_1 P_2}{P_1 + P_2}$$

(b) For parallel combination,

$$P_p = \frac{V^2}{R_p} = V^2\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\text{or} \quad P_p = \frac{V^2}{R_1} + \frac{V^2}{R_2} = P_1 + P_2$$

15. Mobility, $\mu = \frac{\text{Drift velocity}}{\text{Electric field}} = \frac{v_d}{E}$

(i) The charge carriers in an electrolyte are positively and negatively charged ions.

(ii) The charge carriers in an ionised gas are electrons and positively charged ions.

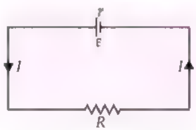
16. Since the electric heater has more power than that of electric bulb and power is reciprocal to resistance for a given supply voltage *i.e.*, $P \propto \frac{1}{R}$.

Hence the resistance of heater coil is less than that of electric bulb. When the heater, which is connected in parallel with the illuminating bulb is made on, it draws more current from the circuit. Due to it, the bulb becomes dim.

After some time, the heater coil becomes hot. Its resistance becomes more. Due to it some current is diverted into bulb, and also the supply voltage maintains the current. As a result of which dimness of the bulb decreases.

OR

(i)



Here, $\varepsilon = 10$ V, $r = 3\ \Omega$, $I = 0.5$ A

Current in the circuit is,

$$I = \frac{\varepsilon}{R + r} \quad \text{or} \quad R = \frac{\varepsilon - Ir}{I} = \frac{10 - 0.5 \times 3}{0.5} = 17\ \Omega$$

(ii) Terminal voltage $V = \varepsilon - Ir = 10 - 0.5 \times 3$

$V = 8.5$ V.

17. Here, $\varepsilon_1 = 1.25$ V, $l_1 = 35$ cm, $l_2 = 63$ cm

$$\text{As } \frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1} \text{ or } \varepsilon_2 = \frac{\varepsilon_1 \times l_2}{l_1} = \frac{1.25 \times 63}{35} = 2.25\text{ V}$$

18. (i) As $R = \frac{\rho l}{A}$

Here $R_1 = \frac{\rho(2l)}{A/2} = 4\rho\frac{l}{A} = 4R,$

So, increase in resistance $= R_1 - R = 4R - R = 3R.$

(ii) Resistivity will not change as it is independent of the dimensions of the wire but depends upon the nature of the wire and also the temperature of the wire.

19. (a) Current, $I = \frac{V}{R} = \frac{6\text{ V}}{6\ \Omega} = 1\text{ A}$

Drift velocity, $v_d = \frac{I}{nAe}$

$$= \frac{1}{10^{29}\times(10^{-6})\times(1.6\times10^{-19})}$$

$$= \frac{1}{1.6}\times10^{-4}\text{ m s}^{-1}$$

Number of electrons in the wire $= nAl$

Kinetic energy of all the electrons

$$= \frac{1}{2}m_e v_d^2 \times nAl$$

$$= \frac{1}{2}\times(9.1\times10^{-31})\times\left(\frac{1}{1.6}\times10^{-4}\right)^2\times 10^{29}\times10^{-6}\times10^{-1}$$

$$\approx 2\times10^{-17}\text{ J}$$

(b) Power loss $= I^2R = 1^2\times 6 = 6\text{ J s}^{-1}$

All the kinetic energy of electrons would be lost in time

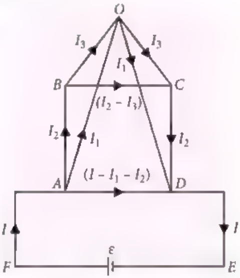
$$= \frac{2\times10^{-17}}{6} = 0.33\times10^{-17}\text{ s} \approx 10^{-17}\text{ s}$$

20. (i) To repair a live line wire Rahul should assure that no current flow through the body. He must wear insulting hand gloves of rubber and insulting shoes of rubber. Then current will not pass through his body and he will remain safe.

(ii) A current of 10 mA or more passing through human body upsets the tiny nerve currents that regulate the body muscular activities. Due to it, the hand muscles contract and the person is unable to let go off the live wires. This results in a severe shock to the person, which may be fatal.

(iii) The insulators work as protectors. That is why the electric wires used in a house are covered with insulting material to protect the person from the direct contact of the electric current. Also the bodies of the electrical instrument, like refrigerator, electric oven etc. are provided with insulators to avoid leakage of current from instrument to earth.

21. Connect a cell of emf ε across A and D. The distribution of currents in the various arms be as shown in figure.



According to Kirchhoff's loop law in a closed loop $BOCB$, $I_3r + I_3r - (I_2 - I_3)r = 0$

or $3I_3 = I_2$ or $I_3 = \frac{I_2}{3}$ ... (i)

In a closed loop $AODA$,

$$I_1r + I_1r - (I - I_1 - I_2)r = 0$$

or $3I_1 + I_2 = I$ ... (ii)

In a closed loop $ABCDA$

$$I_2r + (I_2 - I_3)r + I_2r - (I - I_1 - I_2)\,r = 0$$

or $I = I_1 + 4I_2 - I_3$

$$= I_1 + 4I_2 - \frac{I_2}{3} \quad \text{(using (i))}$$

$$= I_1 + \frac{11}{3}I_2 \quad \text{... (iii)}$$

From (ii) and (iii), we get

$$3I_1 + I_2 = I_1 + \frac{11}{3}I_2 \text{ or } I_2 = \frac{6}{8}I_1 = \frac{3}{4}I_1$$

From (ii), $I = 3I_1 + \frac{3}{4}I_1 = \frac{15}{4}I_1$

In a closed loop $ADEFA$,

$$\varepsilon = (I - I_1 - I_2)r$$

$$= \left(\frac{15}{4}I_1 - I_1 - \frac{3}{4}I_1\right)r = 2I_1r \quad \text{... (iv)}$$

If R is the resistance of network between A and D

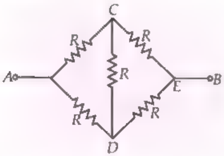
then $\varepsilon = IR = \frac{15}{4} I_1 R$ ... (v)

From (iv) and (v), we get $\frac{15}{4} I_1 R = 2I_1 r$

or $R = \frac{8}{15} r$

OR

(i) The equivalent circuit diagram is as shown in the figure.



It is a balanced Wheatstone bridge. Therefore, the resistance of arm CD is ineffective.

$\therefore$ Resistance of upper arm ACB,

$$R_1 = R + R = 2R$$

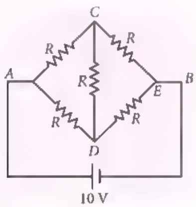
and resistance of lower arm ADB,

$$R_2 = R + R = 2R$$

$\therefore$ Equivalent resistance between A and B is

$$\frac{1}{R_{AB}} = \frac{1}{2R} + \frac{1}{2R} \Rightarrow \frac{1}{R_{AB}} = \frac{2}{2R} \therefore R_{AB} = R$$

(ii)



It is a balanced Wheatstone bridge.

Therefore, resistance of arm CD is ineffective.

No current flows in arm CD.

Resistance of arm $ACB = 2R = 2 \times 2 = 4\ \Omega$

$\therefore$ Current through ABC, $I = \frac{10}{4} = 2.5$ A

22. Internal resistance of a cell depends upon

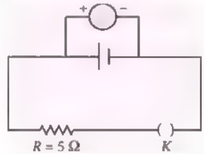
(a) surface area of each electrode.

(b) distance between the two electrodes.

(c) nature, temperature and concentration of electrolyte.

Let internal resistance of cell be r.

The circuit given in question can be redrawn as



Initially when K is open, voltmeter reads 2.2 V.

i.e. emf of the cell, $\varepsilon = 2.2$ V

Later when K is closed, voltmeter reads 1.8 V which is actually the terminal potential difference, V.

i.e. if I is the current flowing, then

$$\varepsilon = I(R + r)$$

$\Rightarrow$ $2.2 = I(5 + r)$ ...(i)

and $V = \varepsilon - Ir$

$1.8 = 2.2 - Ir$ ...(ii)

Solving (i) and (ii), $I = 0.36$ A

Substituting in (ii)

$$r = \frac{0.4}{0.36} \quad \text{or} \quad r = \frac{10}{9}\ \Omega$$

23. The temperature of the wire rises to a certain steady temperature θ if the heat produced per second by the current just becomes equal to the rate of loss of heat by radiation from it.

Heat produced per second by the current

$$= I^2 R = \frac{I^2 \rho l}{\pi r^2}$$

where l is the length, r is radius and ρ is the specific resistance of a wire.

Let H = heat lost per second per unit surface area of the wire.

Neglecting the loss of heat from the end faces of the wire.

Heat lost per second by the wire = $H \times 2\pi r l$

At steady state temperature,

$$H \times 2\pi r l = \frac{I^2 \rho l}{\pi r^2}$$

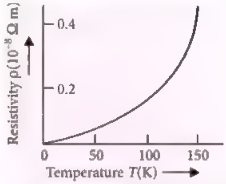
or $H = \frac{I^2 \rho}{2\pi^2 r^3}$ ...(i)

From equation (i) we conclude that the rate of loss of heat (H), which in turn depends upon the temperature of wire, is independent

of length of the wire. Hence the fuses of two wires of same values of r and ρ but of different lengths will melt for the same value of current in each case.

24. Emf of the dc supply, $\varepsilon_1 = 230$ V
total emf of the battery, $\varepsilon_2 = 6 \times 2.0$ V $= 12$ V
total internal resistance of the battery,
$$r = 6 \times 0.25\ \Omega = 1.5\ \Omega$$
series resistance in the circuit, $R = 53\ \Omega$
When the battery is being charged, the emf of the battery (ε_2) acts in a direction opposite to that of the dc supply (*i.e.*, ε_1).
Hence, effective emf in the charging circuit, *i.e.*, $\varepsilon = \varepsilon_1 - \varepsilon_2 = 230$ V $- 12$ V $= 218$ V
Thus, charging current,
$$I = \frac{\varepsilon}{R+r} = \frac{218}{(53+1.5)} = 4\text{ A}$$
(a) Power supplied by the mains $= \varepsilon I = 230 \times 4 = 920$ W
(b) Power dissipated as heat $= I^2(R + r) = (4)^2(53 + 1.5) = 872$ W
The difference of power, *i.e.*, (920 W – 872 W) = 48 W is used up in storing chemical energy in the contents of the accumulator.

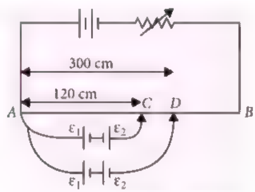
25. $R = \rho \dfrac{l}{A}$,
If $l = 1,\ A = 1 \Rightarrow \rho = R$
Thus, resistivity of a material is numerically equal to the resistance of the conductor having unit length and unit cross-sectional area.
The resistivity of a material is found to be dependent on the temperature. Different materials do not exhibit the same dependence on temperature. Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by,
$$\rho_T = \rho_0\,[1 + \alpha(T - T_0)] \qquad \text{...(i)}$$
where ρ_T is the resistivity at a temperature T and ρ_0 is the same at a reference temperature T_0. α is called the temperature co-efficient of resistivity.
The relation of equation (i) implies that a graph of ρ_T plotted against T would be a straight line. At temperatures much lower than 0°C, the graph, however, deviates considerably from a straight line.



Resistivity ρ_T of metallic conductor as a function of temperature T

26. (i) Here $\varepsilon_1 = 1.5$ V, $l_1 = 60$ cm, $l_2 = 80$ cm
As $\dfrac{\varepsilon_1}{\varepsilon_2} = \dfrac{l_1}{l_2}$ or $\varepsilon_2 = \dfrac{l_2}{l_1} \times \varepsilon_1 = \dfrac{80}{60} \times 1.5 = 2$ V
(ii) No, the circuit will not work. Because there will be smaller fall of potential across the potentiometer wire than the emf of the cell to be determined and hence the balance point will not be obtained on the potentiometer wire.
(iii) No, high resistance will not affect the balance point.

27. (a)



Let ϕ V cm^{-1} be potential gradient of the wire.
Applying Kirchhoff's loop rule to the closed loop ACA, we get
$$\phi(120) = \varepsilon_1 - \varepsilon_2 \qquad \text{...(i)}$$
Again, applying Kirchhoff's loop rule to the closed loop ADA, we get
$$\phi(300) = \varepsilon_1 + \varepsilon_2 \qquad \text{...(ii)}$$
Divide (i) by (ii), we get
$$\frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} = \frac{120}{300} = \frac{2}{5}$$
$5\varepsilon_1 - 5\varepsilon_2 = 2\varepsilon_1 + 2\varepsilon_2$ or $3\varepsilon_1 = 7\varepsilon_2$
$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{7}{3} \qquad \text{...(iii)}$$
(b) Let the position of null point for the cell ε_1 is l_3.

$\therefore \quad \varepsilon_1 = \phi l_3$ ...(iv)

Divide (i) by (iv), we get

$$\frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1} = \frac{120}{l_3} \quad \text{or} \quad 1 - \frac{\varepsilon_2}{\varepsilon_1} = \frac{120}{l_3}$$

$$1 - \frac{3}{7} = \frac{120}{l_3} \quad \text{(Using (iii))}$$

$$\frac{4}{7} = \frac{120}{l_3} \quad \text{or} \quad l_3 = 210 \text{ cm}$$

Sensitivity of a potentiometer is increased by increasing the length of the potentiometer wire.

28. (a) Refer point 2.5, page no. 91 (MTG Excel in Physics)

(b) Let R' be the resistance per unit length of the meter bridge wire,

$$\frac{R_1}{R_2} = \frac{R' \times 40}{R'(100-40)} = \frac{40}{60} = \frac{2}{3}$$

$$\frac{R_1 + 10}{R_2} = \frac{R' \times 60}{R'(100-60)} = \frac{60}{40} = \frac{3}{2}$$

$$\frac{R_1}{R_2} = \frac{2}{3} \quad \text{...(i)}$$

$$\frac{R_1 + 10}{R_2} = \frac{3}{2} \quad \text{...(ii)}$$

Putting the value of R_1 from equation (i) in equation (ii)

$$\frac{2}{3} + \frac{10}{R_2} = \frac{3}{2} \quad \text{or} \quad R_2 = 12\ \Omega$$

From equation (i)

$$\frac{R_1}{12} = \frac{2}{3} \quad \text{or} \quad R_1 = 8\ \Omega$$

OR

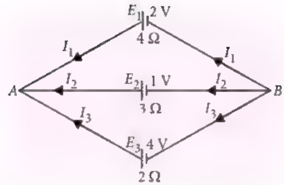
Refer point 9 page no. 86 (MTG Excel in Physics)

29. Refer point 2.3 (9, 10, 11) page no. 89 (MTG Excel in Physics).

OR

Refer point 2.1 page no. 84 (MTG Excel in Physics).

30. The scheme of connections is shown in figure. Let I_1, I_2 and I_3 be the currents flowing through the three cells E_1, E_2 and E_3.



Applying Kirchhoff's junction law at the junction A, we get

$$I_1 + I_2 + I_3 = 0$$

or $\quad I_3 = -(I_1 + I_2)$ ...(i)

Applying Kirchhoff's loop law to the closed loop BE_1AE_2B and we get

$$4I_1 - 2 - 3I_2 + 1 = 0$$

or $\quad 4I_1 - 3I_2 = 2 - 1 = 1$ ... (ii)

Applying the Kirchhoff's loop law to the closed loop BE_1AE_3B, we get

$$4I_1 - 2 - 2I_3 + 4 = 0$$

or $\quad 4I_1 - 2I_3 = 2 - 4 = -2$

or $\quad 4I_1 + 2 \times (I_1 + I_2) = -2$ (Using (i))

or $\quad 6I_1 + 2I_2 = -2$

or $\quad 3I_1 + I_2 = -1$ ... (iii)

Multiplying (iii) by 3 and adding to (ii), we get

$$(9 + 4)I_1 = 1 - 3 = -2 \quad \text{or} \quad I_1 = -\frac{2}{13}\text{A}$$

From (iii),

$$I_2 = -1 - 3I_1 = -1 - 3\left(-\frac{2}{13}\right) = -1 + \frac{6}{13} = -\frac{7}{13}\text{ A}$$

From (i),

$$I_3 = -\left[-\frac{2}{13} - \frac{7}{13}\right] = \frac{9}{13}\text{ A}$$

Note : Negative sign of currents shows that the actual direction is opposite to what has been taken in figure.

OR

(a) Refer point 7 page no. 93 (MTG Excel in Physics)

(b) (i) The emf of the cell connected in main circuit may not be more than the emf of the primary cells whose emfs are to be compared.

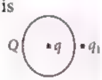
(ii) The positive ends of all cells are not connected to the same end of the wire.

PRACTICE QUESTIONS

TARGET PMTs

Useful for All National and State Level PMTs

1. A thin, metallic spherical shell contains a charge Q on it. A point charge q is placed at the centre of the shell and another charge q_1 is placed outside it as shown in figure. All the three charges are positive. The force on the central charge due to the shell is

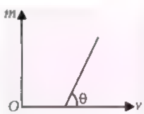


(a) towards left
(b) towards right
(c) upward (d) zero

2. A train 200 m long crosses a bridge 300 m long. It enters the bridge with a speed of 30 m s^{-1} and leaves it with a speed of 50 m s^{-1}. What is the time taken to cross the bridge?
(a) 2.5 s (b) 7.5 s (c) 12.5 s (d) 15.0 s

3. Two identical rooms in a house are connected by an open doorway. The temperatures in the two rooms are maintained at different values. Which room contains more air?
(a) The room with higher temperature.
(b) The room with lower temperature.
(c) The room with higher pressure.
(d) Same, as both have the same pressure and volume.

4. Variation of magnification (m) produced by a thin convex lens versus distance of image from pole of the lens (v) is shown in the graph. Which of the following statements is not correct?



(a) Focal length of the lens is equal to intercept on v-axis.
(b) Focal length of the lens is equal to inverse of slope of the line.
(c) Magnitude of intercept on m-axis is equal to unity.
(d) Magnitude of intercept on v-axis is equal to unity.

5. A source of sound of frequency 500 Hz is moving towards a stationary observer with velocity 30 m s^{-1}. The speed of sound is 330 m s^{-1}. The frequency heard by the observer will be
(a) 545 Hz (b) 580 Hz
(c) 488 Hz (d) 550 Hz

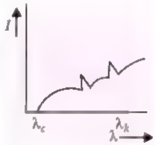
6. A body is projected at such an angle that the horizontal range is three times the greatest height. The angle of projection is
(a) 25°8′ (b) 30°8′
(c) 42°8′ (d) 53°8′

7. If a diamagnetic solution is poured into a U-tube and one arm of this U-tube is placed between the poles of a strong magnet, with the meniscus in line with the field, then the level of solution will
(a) rise (b) fall
(c) oscillate slowly (d) remain as such.

8. Two simple harmonic motions are represented by the equations $y_1 = 0.1\sin\left(100\pi t + \frac{\pi}{3}\right)$ and $y_2 = 0.1\cos\pi t$. The initial phase difference of the velocity of particle 1 with respect to the velocity of particle 2 is
(a) $\frac{\pi}{6}$ (b) $-\frac{\pi}{3}$
(c) $\frac{\pi}{3}$ (d) $-\frac{\pi}{6}$

9. The balancing length for a cell is 560 cm in a potentiometer experiment. When an external resistance of 10 Ω is connected in parallel to the cell, the balancing length changes by 60 cm. The internal resistance of the cell in ohms is
(a) 1.6 (b) 1.4 (c) 1.2 (d) 0.12

10. The intensity of X-rays from a Coolidge tube is plotted against wavelength as shown in the figure. The minimum wavelength found is λ_c and the wavelength of the k_α line is λ_k. As the accelerating voltage is increased



(a) $(\lambda_k - \lambda_c)$ increases (b) $(\lambda_k - \lambda_c)$ decreases
(c) λ_k increases (d) λ_k decreases

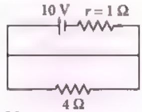
11. A particle of mass m is describing a circular path of radius r with uniform speed. If L is the angular momentum of the particle about the axis of the circle, the kinetic energy of the particle is given by
(a) L^2/mr^2 (b) $L^2/2mr^2$
(c) $2L^2/mr^2$ (d) mr^2L

12. What is the value of inductance L for which the current is maximum in a series LCR circuit with $C = 10\ \mu F$ and $\omega = 1000\ s^{-1}$?
(a) 100 mH (b) 1 mH
(c) 10 mH
(d) Cannot be calculated unless R is known

13. The objects coloured black, grey and white can withstand hostile conditions upto 2800°C. These objects are thrown into a furnace where each of them attains a temperature of 2000°C. Which object will glow the brightest?
(a) The white object (b) The black object
(c) Grey object
(d) All glow with equal brightness

14. A ray of light is passing from air into glass. If the angle of incidence, with respect to the normal to the interface, is increased
(a) Total internal reflection will occur when the angle of incidence equals the critical angle.
(b) Total internal reflection will occur when the angle of incidence is less than the critical angle.
(c) Total internal reflection will occur when the angle of incidence is greater than the critical angle.
(d) Angle of refraction will increase but there will be no total internal reflection.

15. Potential difference across the terminals of the battery having internal resistance r as shown in the figure is



(a) 8 V (b) 10 V
(c) 6 V (d) zero

16. A gun of mass 10 kg fires 4 bullets per second. The mass of each bullet is 20 g and the velocity of the bullet when it leaves the gun is 300 m s^{-1}. The force required to hold the gun when firing is
(a) 6 N (b) 8 N (c) 24 N (d) 240 N

17. A beam of cathode rays is subjected to crossed electric field E and magnetic field B. The fields are adjusted such that the beam is not deflected. The specific charge of the cathode rays is given by (Take, V = potential difference between anode and cathode)
(a) $\dfrac{B^2}{2VE^2}$ (b) $\dfrac{2VB^2}{E^2}$
(c) $\dfrac{2VE^2}{B^2}$ (d) $\dfrac{E^2}{2VB^2}$

18. A transistor is operated in common-emitter configuration at $V_{CE} = 2$ V such that a change in the base current from 100 μA to 200 μA produces a change in the collector current from 5 mA to 10 mA. The current gain is
(a) 100 (b) 150 (c) 50 (d) 75

19. A block has been placed on an inclined plane. The slope angle θ of the plane is such that the block slides down the plane at a constant speed. The coefficient of kinetic friction is equal to
(a) sin θ (b) cos θ
(c) g (d) tan θ

20. 1 g of ice at 0°C is added to 5 g of water at 10°C. If the latent heat is 80 cal g^{-1}, the final temperature of the mixture is
(a) 5°C (b) 0°C
(c) –5°C (d) none of these

21. Two point charges q and $-q$ are placed at points X and Y, respectively. If V_1 is the electric potential at some point P due to q alone and V_2 be due to both charges, then [Position of P, X and Y are not same]
(a) $V_1 > V_2$ for all locations of P
(b) $V_1 = V_2$ for some points
(c) $V_1 > V_2$ for some points
(d) $V_1 < V_2$ for some points

22. Two blocks of masses 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 m. The upper wire has negligible mass and the lower wire has uniform mass of 0.2 kg m^{-1}. The whole system of blocks and support has an upward acceleration of 0.2 m s^{-2}. Acceleration due to gravity is 9.8 m s^{-2}. The tensions at the midpoints of lower and upper wires are respectively given by

(a) 30 N, 50 N (b) 50 N, 30 N
(c) 30 N, 30 N (d) 50 N, 50 N

23. If the kinetic energy of a free electron doubles, its de Broglie wavelength changes by the factor
(a) $1/\sqrt{2}$ (b) $\sqrt{2}$ (c) 1/2 (d) 2

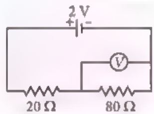
24. Two glass plates are touching at one end and separated by a thin wire at the other end. When a monochromatic parallel beam of wavelength 4200 Å incident normally on the glass plates is reflected, an interference pattern of 30 fringes is observed. If the wavelength of light used is taken 7000 Å instead of 4200 Å, the number of fringes observed will be
(a) 50 (b) 40 (c) 30 (d) 18

25. A wire of length l, radius R is stretched by force F and a second wire of same material, with length $2l$ and radius $2R$, is stretched with a force $2F$; then the ratio of elongations in the two wires is
(a) 1 : 2 (b) 1 : 1
(c) 2 : 1 (d) none of these

26. A hydrogen atom emits a photon corresponding to an electron transition from $n = 5$ to $n = 1$. The recoil speed of hydrogen atom is almost (Take mass of proton = 1.6×10^{-27} kg)
(a) 10 m s^{-1} (b) 2×10^{-2} m s^{-1}
(c) 4 m s^{-1} (d) 8×10^2 m s^{-1}

27. A transformer is having 2100 turns in primary and 4200 turns in secondary. An *ac* source of 120 V, 10 A is connected to its primary. The secondary voltage and current are
(a) 240 V, 5 A (b) 120 V, 10 A
(c) 240 V, 10 A (d) 120 V, 20 A

28. In the figure shown below the e.m.f. of the cell is 2 V and internal resistance is negligible. The resistance of the voltmeter is 80 Ω. The reading of voltmeter will be



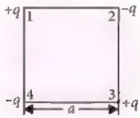
(a) 2.00 V
(b) 1.33 V
(c) 1.60 V
(d) 0.80 V

29. A long spring, when stretched by x cm has a potential energy U. On increasing the length of spring by stretching to nx cm, the potential energy stored in the spring will be
(a) $\frac{U}{n}$ (b) nU
(c) n^2U (d) $\frac{U}{n^2}$

30. The maximum wavelength of a beam of light that can be used to produce photoelectric effect on a metal is 250 nm. The energy of the electrons (in joule) emitted from the surface of the metal when a beam of light of wavelength 200 nm is used, is
(a) 89.61×10^{-22} (b) 69.81×10^{-22}
(c) 18.96×10^{-20} (d) 19.86×10^{-20}

31. In a biprism experiment, by using light of wavelength 5000 Å, 5 mm wide fringes are obtained on a screen 1.0 m away from the coherent sources. The separation between the two coherent sources is
(a) 1.0 mm (b) 0.1 mm
(c) 0.05 mm (d) 0.01 mm

32. The work required to put the four charges at the corners of a square of side a, as shown in figure, is



(a) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}$ (b) $-\frac{2.6}{4\pi\varepsilon_0}\frac{q^2}{a}$

(c) $+\frac{2.6}{4\pi\varepsilon_0}\frac{q^2}{a}$ (d) none of these

33. A radioactive nucleus of mass number A, initially at rest, emits an α-particle with a speed v. What will be the recoil speed of the daughter nucleus?

(a) $\frac{2v}{(A-4)}$ (b) $\frac{2v}{(A+4)}$

(c) $\frac{4v}{(A-4)}$ (d) $\frac{4v}{(A+4)}$

34. A cylindrical tank is filled with water to level of 3 m. A hole is opened at height of 52.5 cm from bottom. The ratio of the area of the hole to that of cross-sectional area of the cylinder is 0.1. The square of the speed with which water is coming out from the orifice is (Take $g = 10\ \text{m s}^{-2}$)

(a) $50\ \text{m}^2\,\text{s}^{-2}$ (b) $40\ \text{m}^2\text{s}^{-2}$

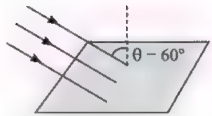
(c) $51.5\ \text{m}^2\,\text{s}^{-2}$ (d) $50.5\ \text{m}^2\,\text{s}^{-2}$

35. A tuning fork produces 8 beats s^{-1} with both, 80 cm and 70 cm of stretched wire of sonometer. Frequency of the fork is

(a) 120 Hz (b) 128 Hz

(c) 112 Hz (d) 240 Hz

36. A square loop of wire of side 5 cm is lying on a horizontal table. An electromagnet above and to one side of the loop is turned on, causing a uniform magnetic field downwards at an angle of 60° to the vertical as shown in figure. The magnetic induction is 0.50 T. The average induced emf in the loop, if the field increases from zero to its final value in 0.2 s is



(a) 5.4×10^{-3} V

(b) 3.12×10^{-3} V

(c) 0

(d) 0.25×10^{-3} V

37. The liquid of a liquid-thermometer should have the following properties :

(a) Large value of specific heat and low value of coefficient of the thermal expansion.

(b) Small value of specific heat and large value of coefficient of the thermal expansion.

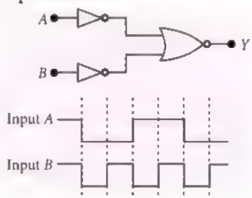
(c) Large value of boiling point and low value of freezing point.

(d) Low value of boiling point and large value of freezing point.

38. If earth suddenly shrinks by one-third of its present radius, the acceleration due to gravity will be

(a) $\frac{2}{3}g$ (b) $\frac{3}{2}g$ (c) $\frac{4}{9}g$ (d) $\frac{9}{4}g$

39. The logic circuit shown in figure has the input waveforms A and B as shown. Pick out the correct ouput waveform.



(a)


(b)

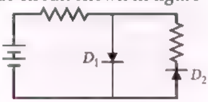

(c)


(d)


40. For obtaining chlorine by electrolysis a current of 100 kW and 125 V is used. (Electro chemical equivalent of chlorine is 0.367×10^{6} kg C^{-1}). The amount of chlorine obtained in one minute will be
(a) 1.7616 g (b) 17.616 g
(c) 0.17161 kg (d) 1.7616 kg

41. A solid sphere of mass M and radius R spins about an axis passing through its centre making 600 rpm. Its KE of rotation is
(a) $\frac{2}{5}\pi^2 MR$ (b) $\frac{2}{5}\pi^2 M^2R^2$
(c) $80\pi^2 MR^2$ (d) $80\pi R$

42. In the diode circuit shown in figure

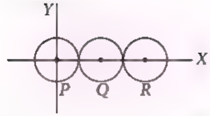


(a) D_1 and D_2 are reverse biased
(b) D_1 and D_2 are forward biased
(c) D_1 is forward biased and D_2 is reverse biased
(d) D_1 is reverse biased and D_2 is forward biased

43. Light of wavelength λ is incident on a slit of width d. The resulting diffraction pattern is observed on a screen at a distance D. The linear width of the principal maximum is then equal to the width of the slit if D equals
(a) (d/λ) (b) $(2\lambda/d)$
(c) $(d^2/2\lambda)$ (d) $(2\lambda^2/d)$

44. A transmitting antenna of height h and the receiving antenna of height 45 m are separated bya distance of 40 km for satisfactory communication in line-of-sight mode. Then the value of h is (Take, radius of the earth = 6400 km)
(a) 15 m (b) 20 m (c) 30 m (d) 25 m

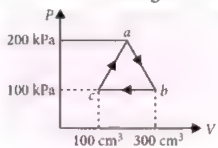
45. Three identical spheres, each of mass 1 kg are kept as shown in the figure, touching each other, with their centres on a straight line. If their centres are marked P, Q, R respectively, the distance of centre of mass of the system from P is



(a) $\frac{PQ+PR+QR}{3}$ (b) $\frac{PQ+PR}{3}$
(c) $\frac{PQ+QR}{3}$ (d) none of these

46. A carrier is simultaneously modulated by two sine waves having modulation indices of 0.3 and 0.4. The total modulation index will be
(a) 0.1 (b) 0.5 (c) 0.7 (d) 0.35

47. A thermodynamic system is taken through the cycle *abca* as shown in the figure. Then



(a) heat rejected by the gas during the process is 10 J
(b) heat absorbed by the gas during the process is 10 J
(c) work done by the gas is 20 J
(d) work done by the gas is –10 J

48. A moving coil galvanometer gives full scale deflection, when a current of 0.005 A is passed through its coil. It is converted into a voltmeter reading upto 5 V using an external resistance of 975 Ω. What is the resistance of the galvanometer coil?
(a) 30 Ω (b) 25 Ω (c) 50 Ω (d) 40 Ω

49. A transparent cube of 15 cm edge contains a small air bubble. Its apparent depth when viewed through one face is 6 cm and when viewed through opposite face is 4 cm. The refractive index of material of cube is
(a) 2.0 (b) 1.5 (c) 1.6 (d) 2.5

50. A current I flows along the length of an infinitely long, straight, thin walled pipe. Then
(a) the magnetic field at all points inside the pipe is the same, but not zero

(b) the magnetic field is zero only on the axis of pipe

(c) the magnetic field is different at different point inside the pipe

(d) the magnetic field at any point inside the pipe is zero

SOLUTIONS

1. **(d):** Net force on q is zero in accordance with electrostatic shielding.

2. **(c) :** Total distance covered while crossing the bridge, $x = (200 + 300)$ m $= 500$ m.

$u = 30 \text{ m s}^{-1}$

$v = 50 \text{ m s}^{-1}$

Using $v^2 - u^2 = 2ax$,

$\Rightarrow \quad 50^2 - 30^2 = 2a\,(500)$

$\Rightarrow \quad 1000a = 1600$

$\Rightarrow \quad a = 1.6 \text{ m s}^{-2}$

Now using $v = u + at$,

$50 = 30 + 1.6\,t$

$\Rightarrow \quad 1.6\,t = 20$

$$\Rightarrow \quad t = \frac{20}{1.6} = 12.5 \text{ s}$$

3. **(b):** $PV = nRT$

For constant R, V and P,

$nT = \text{const.}$,

Let $T_1 > T_2$

$\therefore \quad n_1 < n_2$

i.e., room with higher temperature has lesser number of moles.

4. **(d):** For lens, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Magnification, $m = -\frac{v}{u} = \frac{v}{f} - 1$

Graph between m and v will be a straight line with -1 intercept on m-axis and slope $\tan\theta = 1/f$.

Putting $m = 0$, it gives $v = f$

$\therefore$ (b), (c) and (a) correct.

5. **(d):** From Doppler's effect, the perceived frequency (υ') is given by

$$\upsilon' = \upsilon \frac{v}{v - v_s}$$

where v_s is velocity of source, v is the speed of sound and υ is the original frequency.

Given, $\upsilon = 500$ Hz, $v_s = 30 \text{ m s}^{-1}$, $v = 330 \text{ m s}^{-1}$

$$\upsilon' = 500 \times \frac{330}{330 - 30} \Rightarrow \upsilon' = 500 \times \frac{330}{300} = 550 \text{ Hz}$$

6. **(d):** As, $R = \frac{u^2 \sin 2\theta}{g}$, $H = \frac{u^2 \sin^2\theta}{2g}$

$$\therefore \quad \frac{H}{R} = \frac{\sin^2\theta}{2\sin 2\theta}$$

or $\quad \frac{1}{3} = \frac{1}{4}\tan\theta \qquad$ (Given, $R = 3H$)

or $\quad \tan\theta = \frac{4}{3}$ or $\theta = \tan^{-1}\left(\frac{4}{3}\right) = 53°8'$

7. **(b):** A diamagnetic liquid moves from stronger parts of magnetic field to weaker parts. Therefore the meniscus of the level of solution will fall.

8. **(d):** Here, $y_1 = 0.1\sin(100\pi t + \pi/3)$

Velocity, $v_1 = \frac{dy_1}{dt} = (0.1)(100\pi)\cos(100\pi t + \pi/3)$

$y_2 = 0.1\cos\pi t = 0.1\sin(\pi t + \pi/2)$

Velocity, $v_2 = \frac{dy_2}{dt} = 0.1 \times \pi\cos(\pi t + \pi/2)$

$\therefore$ Phase difference of the velocity of particle 1 w.r.t. particle 2

$= (100\pi t + \pi/3) - (\pi t + \pi/2)$

$= 99\pi t + \pi/3 - \pi/2$

At $t = 0$, phase difference, $\pi/3 - \pi/2 = -\pi/6$

9. **(c) :** Internal resistance, $r = \frac{R(l_1 - l_2)}{l_2}$

$$= \frac{10(560 - 500)}{500} = \frac{10 \times 60}{500}$$

$= 1.2\ \Omega$

10. **(a) :** Wavelength λ_k is independent of the accelerating voltage (V), while the minimum wavelength λ_c is inversely proportional to V. Therefore, as V increases λ_k remains unchanged whereas λ_c decreases, so $\lambda_k - \lambda_c$ increases.

11. **(b):** In circular motion of a particle of mass m along a path of radius r with a constant speed v (say), linear momentum $= mv$ which is always perpendicular to the radius vector.

Hence, angular momentum of the particle about the axis of the circle

= moment of linear momentum

= linear momentum × perpendicular distance w.r.t. axis of rotation

$$L = mvr, \therefore\ v = \frac{L}{mr}$$

and $K = \frac{1}{2}mv^2 = \frac{L^2}{2mr^2}$

12. (a) : In resonance condition, maximum current flows in the circuit.

$$X_L = X_C \quad \text{(At resonance)}$$

$$\omega L = \frac{1}{\omega C}$$

or $L = \frac{1}{\omega^2 C}$

Here, $\omega = 1000\ s^{-1}$, $C = 10\ \mu F = 10 \times 10^{-6}$ F

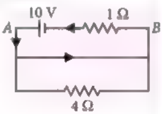
$$\therefore \quad L = \frac{1}{(1000)^2 \times 10 \times 10^{-6}} = 0.1\ H = 100\ mH$$

13. (b): Black object, which can absorb maximum can also emit maximum (Kirchhoff's law).

14. (d): Since light is going from rarer to denser medium hence no *TIR* will occur.

15. (d): 4 Ω resistor is short circuited.

$$\Rightarrow \quad I = \frac{10}{1} = 10\ A$$



Applying KVL in upper loop

$$V_A - 10 + 10 \times 1 = V_B$$

or $V_A - V_B = 0$

16. (c) : Momentum of one bullet, $p = mv$

$$= 20 \times 10^{-3} \times 300$$
$$= 6\ kg\ m\ s^{-1}$$

N = number of bullet per sec = 4

$\therefore \frac{dp}{dt}$ = change of momentum per sec or force

$$= N(p - 0) = 4 \times 6 = 24\ N$$

17. (d): As the electron beam is not deflected, then, $F_m = F_e$

or $Bev = Ee$

or $v = \frac{E}{B}$ ...(i)

As the electron moves from cathode to anode, its potential energy at the cathode appears as its kinetic energy at the anode. As V is the potential difference between the anode and cathode, then potential energy of the electron at cathode = eV. Also, kinetic energy of the electron at anode = $\frac{1}{2}mv^2$

According to law of conservation of energy

$$\frac{1}{2}mv^2 = eV$$

or $v = \sqrt{\frac{2eV}{m}}$ ...(ii)

From equations (i) and (ii), we have

$$\sqrt{\frac{2eV}{m}} = \frac{E}{B}$$

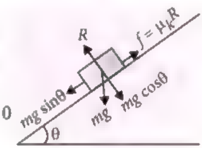
or $\frac{e}{m} = \frac{E^2}{2VB^2}$

18. (c) : As $\beta = \left(\frac{\Delta I_c}{\Delta I_b}\right)_{V_{CE}}$

$$\beta = \frac{(10 \times 10^{-3} - 5 \times 10^{-3})A}{(200 \times 10^{-6} - 100 \times 10^{-6})A}$$

$$= \frac{5 \times 10^{-3}}{100 \times 10^{-6}} = 50$$

19. (d): Because the block is sliding down the inclined plane with constant speed, hence acceleration of the block down the plane must be equal to zero.



$mg\sin\theta - f = ma$

or $g\sin\theta - \mu_k g\cos\theta = 0$

or $\tan\theta = \mu_k$

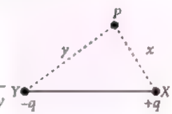
20. (b): Heat lost by 5 g water to fall its temperature by 10°C

$$Q_1 = 5 \times 1 \times 10 = 50\ cal$$

Latent heat of 1 g ice, $Q_2 = 1 \times 80 = 80$ cal

As $Q_1 < Q_2$ therefore final temperature = 0°C

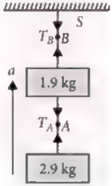
21. (a) : $V_1 = \frac{q}{4\pi\varepsilon_0 x}$



$$V_2 = \frac{q}{4\pi\varepsilon_0 x} - \frac{q}{4\pi\varepsilon_0 y}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x} - \frac{1}{y}\right] < V_1$$

22. (a) : Because the system is accelerated upward, tension at any point will be,



$$T = m(g + a)$$

For point A,

$$m = 2.9 + \frac{0.2}{2} = 3 \text{ kg}$$

$\therefore \quad T_A = 3(9.8 + 0.2) = 30$ N

For point B,

$$m = 2.9 + 0.2 + 1.9 + 0 = 5 \text{ kg}$$

$\therefore \quad T_B = 5(9.8 + 0.2) = 50$ N

23. (a) : As de Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}}$$

i.e., $\lambda \propto \frac{1}{\sqrt{K}}$

When K is doubled, λ changes by the factor $1/\sqrt{2}$.

24. (d): Number of fringes $= \frac{30\beta}{\beta_1}$

$$= 30 \times \frac{4200}{7000} = 18$$

25. (b): As $\Delta l = \frac{Fl}{\pi r^2 Y}$

$$\therefore \quad \frac{\Delta l_1}{\Delta l_2} = \frac{F_1}{F_2} \times \frac{l_1}{l_2} \times \frac{r_2^2}{r_1^2}$$

Here, $F_2 = 2F, F_1 = F, r_2 = 2R, r_1 = R, l_2 = 2l, l_1 = l$

$$\frac{\Delta l_1}{\Delta l_2} = \frac{F}{2F} \times \frac{l}{2l} \times \frac{4R^2}{R^2} = 1$$

26. (c) : The hydrogen atom before the transition was at rest. Therefore, from conservation of momentum

$$p_{\text{H-atom}} = p_{\text{photon}} = \frac{E_{\text{radiated}}}{c}$$

$$= \frac{13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]\text{eV}}{c}$$

$$\Rightarrow 1.6 \times 10^{-27} \times v = \frac{13.6\left[\frac{1}{1^2} - \frac{1}{5^2}\right] \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

or $\quad v = 4.352 \text{ m s}^{-1} \approx 4 \text{ m s}^{-1}$

27. (a) : As $V_s = \frac{N_s}{N_p} V_p$

$$\therefore \quad \frac{4200}{2100} \times 120 = 240 \text{ V}$$

and $I_s = \frac{N_p}{N_s} I_p$

$$\therefore \quad \frac{2100}{4200} \times 10 = 5 \text{ A}$$

28. (b): The voltmeter is in parallel with 80 Ω resistance. Let equivalent resistance be R'. Here, R' = 40 Ω. Now, 20 Ω resistance is in series with R'. So, the equivalent resistance of the circuit = 20 + 40 = 60 Ω.

Current in the circuit = (2/60) A

Current across 80 Ω resistance

$$= \frac{1}{2} \times \frac{2}{60} = \frac{1}{60} \text{ A}$$

$\therefore \quad$ Reading of voltmeter $= 80 \times \frac{1}{60} = 1.33$ V

29. (c) : Initially, potential energy $= \frac{1}{2}kx^2$

$$\Rightarrow \quad U = \frac{1}{2}kx^2$$

or $\quad 2U = kx^2 \Rightarrow k = \frac{2U}{x^2}$

When it is stretched to nx cm, then

$$PE = \frac{1}{2}kx_1^2 = \frac{1}{2} \times \frac{2U}{x^2} \times n^2x^2 = n^2U$$

$\therefore \quad$ Potential energy stored in the spring $= n^2U$

30. (d): Here, $\lambda_0 = 250 \text{ nm} = 250 \times 10^{-9}$ m

$\lambda = 200 \text{ nm} = 200 \times 10^{-9}$ m

From Einstein's photoelectric equation, we get

$$E = \frac{1}{2}mv^2 = h\upsilon - h\upsilon_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

$$= 6.62 \times 10^{-34} \times 3 \times 10^8 \times \left[\frac{1}{200} - \frac{1}{250}\right] \times \frac{1}{10^{-9}}$$

$$= 19.86 \times 10^{-20} \text{ J}$$

31. (b): As $\beta = \frac{D\lambda}{d}$

Here, $\beta = 5 \times 10^{-3}$ m, $\lambda = 5000 \times 10^{-10}$ m and $D = 1$ m

$\therefore$ separation between two coherent sources

$$d = \frac{D\lambda}{\beta} = \frac{1 \times 5000 \times 10^{-10}}{5 \times 10^{-3}} = 0.1 \text{ mm}$$

32. (b): Work done = Potential energy of configuration of charges

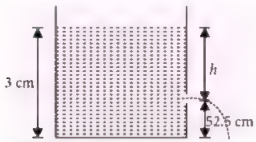
$$= \frac{1}{4\pi\varepsilon_0 a}[q(-q)+(-q)q+q(-q)+(-q)(q)] + \frac{(-q)(-q)+q^2}{4\pi\varepsilon_0 a\sqrt{2}}$$

$$= \frac{1}{4\pi\varepsilon_0}\left[-\frac{4q^2}{a}+\frac{2q^2}{a\sqrt{2}}\right] = \frac{-2.6}{4\pi\varepsilon_0}\frac{q^2}{a}$$

33. (c): As per conservation law of momentum, $A \times 0 = 4v + (A-4)v_r$

$\therefore$ Recoil speed, $|v_r| = \dfrac{4v}{(A-4)}$

34. (a): Let A be the are of cross section of tank, a be the area of hole, v_e be the velocity of efflux, h be the height of liquid above the hole,



Let v be the speed with which the level decreases in the container. Using equation of continuity, we get

$$av_e = Av \quad \text{or} \quad v = \frac{av_e}{A}$$

Using Bernoulli's theorem, we have

$$P_0 + h\rho g + \frac{1}{2}\rho v^2 = P_0 + \frac{1}{2}\rho v_e^2$$

$$h\rho g + \frac{1}{2}\rho\left(\frac{av_e}{A}\right)^2 = \frac{1}{2}\rho v_e^2$$

or $$v_e^2 = \frac{2hg}{1-(a^2/A^2)} = \frac{2\times(3-0.525)\times 10}{1-(0.1)^2}$$

$$= 50 \text{ m}^2\text{ s}^{-2}$$

35. (a): Here, $l_1 = 80$ cm, $l_2 = 70$ cm

$$\therefore \frac{\upsilon_2}{\upsilon_1} = \frac{l_1}{l_2} = \frac{80}{70} = \frac{8}{7}$$

If υ is frequency of tuning fork, then

$\upsilon_2 - \upsilon = 8$ and $\upsilon - \upsilon_1 = 8$

$\therefore$ $\upsilon_2 - \upsilon_1 = 16$

or $\dfrac{8\upsilon_1}{7} - \upsilon_1 = 16$, or $\upsilon_1 = 112$ Hz

$\therefore$ $\upsilon = \upsilon_1 + 8 = 112 + 8 = 120$ Hz

36. (b): $$\varepsilon = \frac{d\phi}{dt} = \frac{(NBA\cos\theta - 0)}{t}$$

$$= \frac{1\times 0.5\times 25\times 10^{-4}\cos 60^\circ - 0}{0.2}$$

or $\varepsilon = 3.12 \times 10^{-3}$ V.

37. (b): Small value of specific heat and large value of coefficient of the thermal expansion.

38. (d): As, $g = \dfrac{GM}{R^2}$ *i.e.*, $g \propto \dfrac{1}{R^2}$

Now radius of earth

$R' = R - R/3 = 2R/3$

So $$\frac{g'}{g} = \frac{R^2}{(2R/3)^2} = \frac{9}{4} \text{ or } g' = \frac{9}{4}g$$

39. (d): The output of upper NOT gate = $\overline{A}$

The output of lower NOT gate = $\overline{B}$

The output of NOR gate is

$$Y = \overline{\overline{A}+\overline{B}} = \overline{\overline{A}}\cdot\overline{\overline{B}} = A\cdot B$$

Thus, given combination of gates is AND gate.

$\therefore$ Truth table

A	B	Y
1	1	1
0	0	0
0	1	0
1	0	0
1	1	1
0	0	0

Therefore the graph (d) is correct according to given inputs of graph.

40. (b): As, $m = zIt = z\left(\dfrac{P}{V}\right)t$

Here, $z = 0.367 \times 10^6$ kg C^{-1},

$P = 100$ kW $= 100 \times 10^3$ W

$V = 125$ V, $t = 1$ minute $= 60$ s

$$\therefore m = 0.367\times 10^{-6}\times\left(\frac{100\times 1000}{125}\right)\times 60 \text{ kg}$$

$= 0.017616$ kg $= 17.616$ g.

41. **(c) :** KE of rotation $= \frac{1}{2}I\omega^2 = \frac{1}{2}\times\frac{2}{5}MR^2(2\pi\upsilon)^2$

$$= \frac{1}{5}\times 4\pi^2\upsilon^2 MR^2$$

$$= 0.8\pi^2\left(\frac{600}{60}\right)^2 MR^2 = 80\pi^2 MR^2$$

42. **(c)**

43. **(c) :** Linear width of principal maximum

$$= \frac{2\lambda}{d}\times D$$

According to given problem,

$$d = \frac{2\lambda}{d}\times D \text{ or } \frac{d^2}{2\lambda} = D$$

44. **(b):** As, $d = \sqrt{2Rh_T} + \sqrt{2Rh_R}$

$$\therefore \quad 40\times 1000 = \sqrt{2\times 6.4\times 10^6\times h} + \sqrt{2\times 6.4\times 10^6\times 45}$$

or $\quad 40\times 10^3 = \sqrt{2\times 6.4\times 10^6\times h} + 24\times 10^3$

or $\quad h = \frac{[(40-24)10^3]^2}{2\times 6.4\times 10^6} = 20 \text{ m}$

45. **(b):** As is clear from symmetry of figure, centre of mass of the system is at Q. It's distance from P is

$$x = \frac{m\times 0 + m\times PQ + m\times PR}{3m} \text{ or } x = \frac{PQ+PR}{3}$$

46. **(b):** Here, $\mu_1 = 0.3$ and $\mu_2 = 0.4$

$$\mu = \sqrt{\mu_1^2+\mu_2^2} = \sqrt{0.3^2+0.4^2}$$

$$= \sqrt{0.09+0.16} = \sqrt{0.25} = 0.5$$

47. **(b):** Work done by gas = area under the curve

$$= \frac{1}{2}\times 200\times 100 = 10\times 10^3 \text{ kPa cm}^3 = 10 \text{ J}$$

$\Delta Q = \Delta W = 10$ J (in a cyclic process)

48. **(b):** Here, $I_g = 0.005$ A, $V = 5$ V, $R = 975\ \Omega$, $G = ?$

Now, $R = \frac{V}{I_g} - G$

or $\quad G = \frac{V}{I_g} - R = \frac{5}{0.005} - 975 = 25\ \Omega$

49. **(b):** Here, real depth, $x = 15$ cm

apparent depth, $y = 6 + 4 = 10$ cm

$$\mu = \frac{x}{y} = \frac{15}{10} = 1.5$$

50. **(d):** There is no current inside the pipe, hence there is no magnetic field inside the pipe, following Ampere's circuital law.

BRAIN MAP

MOTION IN A STRAIGHT LINE

To describe the motion of an object, one must be able to specify the location of the object at all time ... be accompanied by the rotation or vibration of the object.

One Dimensional Motion

- The motion of an object is said to be one dimensional motion if only one out of three coordinates specifying the position of the object changes with time.

Distance and Displacement

- **Distance :** The length of the actual path traversed by a body during motion in a given interval of time is called distance travelled by the body.
- **Displacement :** The displacement of a body is defined as the shortest distance between the two positions of the body in a particular direction. It is given by the vector drawn from the initial position to its final position.

Speed and Velocity

- **Speed :** Speed of a body is defined as the distance moved per unit time.

$$v = s/t$$

- **Average speed :** Average speed is defined as the ratio of the total distance travelled by the body to the total time taken.

$$v_{av} = \frac{s_1 + s_2 + \ldots}{t_1 + t_2 + \ldots}$$

- **Velocity :** Velocity of a body is defined as the time rate of change of displacement of the body

$$\vec{v} = \frac{\vec{x}}{t}$$

- **Average velocity :** Average velocity is defined as the ratio of the displacement to the time interval for which the motion takes place.

$$|\vec{v}_{av}| = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

- **Instantaneous velocity :** The velocity of a body at a given instant of time during motion is known as instantaneous velocity

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$$

Uniform and Non-uniform Motion

- **Uniform motion:** An object is said to be in uniform motion, if it covers equal distances in equal intervals of time, however small these intervals may be in the same fixed direction.
- **Non-uniform motion:** A body is said to be in non-uniform motion if its velocity changes with time.

Acceleration

- **Acceleration :** Acceleration of a body is defined as the time rate of change of velocity of a body.

i.e. Acceleration $= \dfrac{\text{change in velocity}}{\text{time taken}}$

- **Average acceleration :** Average acceleration is defined as the ratio of the change in velocity to the time interval during which the change occurs.

$$\vec{a}_{av} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

- **Instantaneous acceleration :** The acceleration of a body at a given instant of time is known as instantaneous acceleration.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

Positive and Negative Accelerations

- If the velocity of an object increases with time, its acceleration is positive. If velocity of an object decreases with time, its acceleration is negative. Negative acceleration is also called retardation or deceleration.

Position-Time Graph

- It is the graph between the time t and position x of a particle relative to a fixed origin. Its slope at any point gives the instantaneous velocity at the point.
- For a stationary object, the position-time graph is a straight line parallel to the time axis.
- For a body in uniform motion, the position-time graph is a straight line inclined to the time axis.
- For uniformly accelerated motion, the position-time graph is a parabola.
- For infinite speed, position-time graph is straight line parallel to position axis.

Velocity-Time Graph

- It is a graph of time versus velocity. Its slope at any point gives the acceleration at the corresponding instant. Distance covered in time t equals area under the velocity-time graph bounded by the time axis.
- For uniform motion, the velocity-time graph is a straight line parallel to the time axis.
- For uniform acceleration, the velocity-time graph is a straight line inclined to the time axis.
- Uniform acceleration is positive for positive slope of velocity-time graph and is negative for negative slope of v-t graph.
- For variable acceleration, the velocity-time graph is a curve.

Relative Velocity

- The relative velocity of an object B with respect to object A when both are in motion is the rate of change of position of object B with respect to object A. $\vec{v}_{BA} = \vec{v}_B - \vec{v}_A$, $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$
- Relative velocity of object B w.r.t. object A, $v_{AB} = v_A - v_B$
- Relative velocity of object A w.r.t. object B, $v_{AB} = v_A + v_B$
- When both the objects A and B move in the same direction, $\sqrt{v_A^2 + v_B^2 - 2v_Av_B\cos(180° - \theta)} = \sqrt{v_A^2 + v_B^2 - 2v_Av_B\cos\theta}$
- When the object B moves in the opposite direction of A,
- When v_A and v_B are inclined to each other at angle θ, $\tan\beta = \dfrac{v_B\sin\theta}{v_A - v_B\cos\theta}$.

Equations of Motion

- Equations of motion for a uniform accelerated motion

(i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$ (iii) $v^2 - u^2 = 2as$ (iv) $s_n = u + \frac{a}{2}(2n - 1)$

where u is initial velocity, v is final velocity, a is uniform acceleration, s is distance travelled in time t, s_n is distance covered in n^{th} second. These equations are not valid if the acceleration is non-uniform.

- Equations of motion for a body under gravity

(i) $v = u + gt$ (ii) $h = ut + \frac{1}{2}gt^2$ (iii) $v^2 = u^2 + 2gh$ (iv) $h_n = u + \frac{1}{2}g(2n - 1)$

- When a body is thrown vertically upward, its velocity decreases and the value of g is taken negative.
- For a body thrown vertically upward with initial velocity u, we have

(i) Maximum height reached, $h = \dfrac{u^2}{2g}$

(ii) Time of ascent = Time of descent $= \dfrac{u}{g}$

(iii) Total time of flight (time to come back to the point of projection) $= \dfrac{2u}{g}$

(iv) Velocity of fall at the point of projection $= u$

(v) Velocity attained by a body dropped from height h, $= \sqrt{2gh}$

Acceleration-Time Graph

- When the graph is a straight line and parallel to time axis then acceleration is constant
- When the graph is oblique straight line having positive slope, then acceleration is uniformly increasing.
- When the graph is an oblique straight line having negative slope, then acceleration is uniformly decreasing.

SOLVED PAPER 2014

Kerala PMT

1. The dimensions of mobility of charge carriers are
(a) $M^{-2}T^2A$ (b) $M^{-1}T^2A$
(c) $M^{-2}T^3A$ (d) $M^{-1}T^3A$
(e) $M^{-1}T^2A^{-1}$

2. The acceleration of a moving body is found from the
(a) area under velocity-time graph
(b) area under displacement-time graph
(c) slope of distance-time graph
(d) slope of velocity -time graph
(e) area under acceleration- time graph

3. A ball thrown vertically upwards after reaching a maximum height h, returns to the starting point after a time of 10 s. Its displacement is
(a) h (b) $2h$ (c) $10h$ (d) $20h$
(e) zero

4. If the angles of projection of a projectile with same initial velocity exceed or fall short of 45° by equal amounts α, then the ratio of horizontal ranges is
(a) 1 : 2 (b) 1 : 3 (c) 1 : 4 (d) 1 : 1
(e) $1:\sqrt{2}$

5. If the length of seconds' hand of a clock is 10 cm, the speed of its tip (in cm s^{-1}) is nearly
(a) 2 (b) 0.5 (c) 1.5 (d) 3
(e) 1

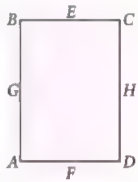
6. The retarding acceleration of 7.35 m s^{-2} due to frictional force stops the car of mass 400 kg travelling in a road. The coefficient of friction between the tyre of the car and the road is
(a) 0.55 (b) 0.75 (c) 0.70 (d) 0.65
(e) 0.80

7. A hammer weighing 3 kg strikes the head of a nail with a speed of 2 m s^{-1} drives by 1 cm into the wall. The impulse imparted to the wall is
(a) 6 N s (b) 3 N s (c) 2 N s (d) 12 N s
(e) 18 N s

8. If two persons A and B take 2 seconds and 4 seconds respectively to lift an object to the same height h, then the ratio of their powers is
(a) 1 : 2 (b) 1 : 1 (c) 2 : 1 (d) 1 : 3
(e) 3 : 1

9. If a machine gun fires n bullets per second each with kinetic energy K, then the power of the machine gun is
(a) nK^2 (b) $\frac{K}{n}$ (c) n^2K (d) nK
(e) $\frac{n}{K}$

10. The moment of inertia of the rectangular plate $ABCD$, $(AB = 2BC)$ is minimum along the axis



(a) GH
(b) EF
(c) BC
(d) AC (e) AB

11. The position of centre of mass of a system of particles does not depend upon the
(a) mass of particles
(b) symmetry of the body
(c) position of the particles
(d) relative distance between the particles
(e) nature of particles

12. The relation between escape velocity (V_e) from the surface of the earth and the orbital velocity (V_o) is
(a) $\sqrt{2}V_e = V_o$ (b) $V_e = \sqrt{2}V_o$
(c) $V_e = 2V_o$ (d) $4V_e = 3V_o$
(e) $V_e = \sqrt{3}V_o$

13. The time period of an earth's satellite revolving at a height of 35800 km is
(a) 24 hours (b) 100 minutes
(c) 12 hours (d) 48 hours
(e) 52 hours

14. A solid ball of volume V experiences a viscous force F when falling with a speed v in a liquid. If another ball of volume $8V$ with the same velocity v is allowed to fall in the same liquid, it experiences a force
(a) F (b) $16F$ (c) $4F$ (d) $8F$
(e) $2F$

15. For most of the materials, Young's modulus (Y) and rigidity modulus (G) are related as
(a) $G = 3Y$ (b) $G = \frac{Y}{3}$
(c) $G = \frac{3}{2}Y$ (d) $G = \frac{Y}{8}$
(e) $10G = 3Y$

16. The pressure on an object of bulk modulus B undergoing hydraulic compression due to a stress exerted by surrounding fluid having volume strain $\left(\frac{\Delta V}{V}\right)$ is
(a) $B^2\left(\frac{\Delta V}{V}\right)$ (b) $B\left(\frac{\Delta V}{V}\right)^2$
(c) $\frac{1}{B}\left(\frac{\Delta V}{V}\right)$ (d) $\frac{1}{B^2}\left(\frac{\Delta V}{V}\right)$
(e) $B\left(\frac{\Delta V}{V}\right)$

17. If d is the average diameter of the molecule, then the mean free path of the molecules between two successive collisions is proportional to
(a) d (b) d^2 (c) $\frac{1}{d}$ (d) $\frac{1}{d^2}$
(e) $\frac{1}{d^3}$

18. Which one of the following is a wrong statement in kinetic theory of gases?
(a) The gas molecules are in random motion.
(b) The gas molecules are perfect elastic spheres.
(c) The volume occupied by the molecules of a gas is negligible.
(d) The force of attraction between the molecules is negligible.
(e) The collision between molecules are inelastic.

19. The change in internal energy of a thermodynamical system which has absorbed 2 kcal of heat and done 400 J of work is (1 cal = 4.2 J)
(a) 2 kJ (b) 8 kJ (c) 3.5 kJ (d) 5.5 kJ
(e) 4.2 kJ

20. When the displacement of a particle executing simple harmonic motion is half its amplitude, the ratio of its kinetic energy to potential energy is
(a) 1 : 3 (b) 2 : 1 (c) 3 : 1 (d) 1 : 2
(e) 2 : 3

21. A body oscillates with SHM according to the equation (in SI units), $x = 5\cos\left(2\pi t + \frac{\pi}{4}\right)$. Its instantaneous displacement at t = 1 second is
(a) $\frac{\sqrt{2}}{5}$ m (b) $\frac{1}{\sqrt{3}}$ m (c) $\frac{1}{\sqrt{2}}$ m (d) $\frac{1}{2}$ m
(e) $\frac{5}{\sqrt{2}}$ m

22. Identify the correct statement.
(a) Transverse wave can propagate in gases.
(b) Transverse wave consists of compressions and rarefactions.
(c) Longitudinal wave can propagate in solids, liquids and gases.
(d) In a longitudinal wave, particles of the medium vibrate perpendicular to the direction of propagation.
(e) In a longitudinal wave, the higher density corresponds to rarefactions.

23. The speed of sound in air
(a) decreases with temperature
(b) increases with pressure
(c) increases with humidity
(d) decreases with pressure
(e) increases with density

24. The bulk modulus of a spherical object is B. If it is subjected to uniform pressure p, the fractional decrease in radius is

(a) $\frac{p}{B}$ (b) $\frac{p}{3B}$ (c) $\frac{3p}{B}$ (d) $\frac{B}{3p}$

(e) $\frac{3B}{p}$

25. An electric dipole of dipole moment $\vec{p}$ is placed in a uniform external electric field $\vec{E}$. Then the
(a) torque experienced by the dipole is $\vec{E}\times\vec{p}$.
(b) torque is zero if $\vec{p}$ is perpendicular to $\vec{E}$.
(c) torque is maximum if $\vec{p}$ is perpendicular to $\vec{E}$.
(d) potential energy is maximum if $\vec{p}$ is parallel to $\vec{E}$.
(e) potential energy is maximum if $\vec{p}$ is perpendicular to $\vec{E}$.

26. Electric field at a point of distance r from a uniformly charged wire of infinite length having linear charge density λ is directly proportional to
(a) r^{-1} (b) r (c) r^2 (d) r^{-2}
(e) $\sqrt{r}$

27. When 4 ampere current flows for 2 minutes in an electroplating experiment, m gram of silver is deposited. Then the amount (in gram) of silver deposited by 6 ampere current flowing for 40 seconds is
(a) $4m$ (b) $\frac{m}{2}$ (c) $2m$ (d) $\frac{m}{4}$
(e) $\frac{3m}{4}$

28. A uniform wire of resistance 9 Ω is joined end-to-end to form a circle. Then the resistance of the circular wire between any two diametrically opposite points is
(a) 6 Ω (b) 3 Ω (c) $\frac{9}{4}$ Ω (d) $\frac{3}{2}$ Ω
(e) 1 Ω

29. The temperature coefficient of resistance of an alloy used for making resistors is
(a) small and positive (b) small and negative
(c) large and positive (d) large and negative
(e) zero

30. The deflection in a moving coil galvanometer is
(a) directly proportional to the torsional constant of the spring
(b) independent of the torsional constant of the spring
(c) inversely proportional to the area of the coil
(d) inversely proportional to the current flowing through it
(e) directly proportional to the number of turns in the coil

31. When a magnetic field is applied on a stationary electron, it
(a) remains stationary
(b) spins about its own axis
(c) moves in the direction of the field
(d) moves perpendicular to the direction of the field
(e) move opposite to the direction of the field.

32. A toroid having 200 turns carries a current of 1 A. The average radius of the toroid is 10 cm. The magnetic field at any point in the open space inside the toroid is
(a) 4×10^{-3} T (b) zero
(c) 0.5×10^{-3} T (d) 3×10^{-3} T
(e) 2×10^{-3} T

33. Transformer is used to
(a) convert ac to dc voltage
(b) convert dc to ac voltage
(c) obtain desired dc power
(d) obtain desired ac voltage and current
(e) obtain desired dc voltage and current

34. If an *LCR* series circuit is connected to an ac source, then at resonance the voltage across
(a) *R* is zero
(b) *R* equals the applied voltage
(c) *C* is zero
(d) *L* equals the applied voltage
(e) *L* is zero

35. A dynamo converts
(a) mechanical energy into thermal energy
(b) electrical energy into thermal energy

(c) thermal energy into electrical energy
(d) mechanical energy into electrical energy
(e) electrical energy into mechanical energy

36. The electromagnetic waves detected using a thermopile and used in physical therapy are
(a) gamma radiations
(b) X-rays
(c) ultra-violet radiations
(d) infra-red radiations
(e) micro-wave radiations

37. Two lenses of power 15 and –3 dioptre are placed in contact. The focal length of the combination is
(a) 10 cm (b) 15 cm (c) 12 cm (d) 18 cm
(e) 8.33 cm

38. The speed of light in an isotropic medium depends on
(a) the nature of the source
(b) its wavelength
(c) its direction of propagation
(d) its intensity
(e) the motion of the source relative to the medium

39. Astigmatism is corrected using
(a) cylindrical lens
(b) plano-convex lens
(c) plano-concave lens
(d) convex lens
(e) concave lens

40. If the wavelength of incident light falling on a photosensitive material decreases, then
(a) photoelectric current increases
(b) stopping potential decreases
(c) stopping potential remains constant
(d) photoelectric current decreases
(e) stopping potential increases

41. After 300 days, the activity of a radioactive sample is 5000 dps (disintegrations per sec). The activity becomes 2500 dps after another 150 days. The initial activity of the sample in dps is
(a) 20000 (b) 10000
(c) 7000 (d) 25000
(e) 15000

42. The control rods used in a nuclear reactor can be made up of
(a) graphite (b) cadmium
(c) uranium (d) barium
(e) lead

43. The fusion reaction in the sun is a multi-step process in which the
(a) helium is burned into deuterons.
(b) helium is burned into hydrogen.
(c) deuteron is burned into hydrogen.
(d) hydrogen is burned into helium.
(e) helium is burned into neutrons.

44. Identify the wrong statement.
(a) In conductors, the valence and conduction bands overlap.
(b) Substances with energy gap of the order of 10 eV are insulators.
(c) The resistivity of semiconductors is lower than metals.
(d) The conductivity of metals is high.
(e) The resistivity of a semiconductor is lower than that of an insulator.

45. Identify the wrong statement with reference to a solar cell.
(a) It is a *p*-*n* junction diode with no external bias.
(b) It uses materials of high optical absorption.
(c) It uses materials with band gap of 5 eV.
(d) It converts light energy into electrical energy.
(e) It uses materials such as GaAs, Si.

46. The minimum number of NAND gates used to construct an OR gate is
(a) 4 (b) 6 (c) 5 (d) 3
(e) 2

47. An AM radio station operating at 630 kHz is permitted to broadcast audio frequencies up to 6 kHz. The band pass filter in its modulation circuit can retain the frequencies
(a) 636 kHz, 630 kHz (b) 12 kHz, 6 kHz
(c) 1260 kHz, 6 kHz (d) 1260 kHz, 630 kHz
(e) 6 kHz, 630 kHz

48. A transducer, in communication system is a device that
(a) is a part of the antenna.
(b) is a combination of a receiver and a transmitter.
(c) converts audio signals into video signals.
(d) detects the incoming signal.
(e) converts physical variable into corresponding variations in the electrical signal.

SOLUTIONS

1. (b) : Mobility, $\mu = \frac{\text{Drift velocity } (v_d)}{\text{Electric field } (E)}$

$$\therefore \quad [\mu] = \frac{[v_d]}{[E]} = \frac{[M^0LT^{-1}]}{[MLT^{-3}A^{-1}]} = [M^{-1}T^2A]$$

2. (d) : The slope of velocity-time graph gives the acceleration of a body.

3. (e) : Since the ball returns back to its starting point, therefore its displacement is zero.

4. (d) : Let u be initial velocity of the projectile. For angle of projection (45° + α), horizontal range is

$$R_1 = \frac{u^2 \sin 2(45° + \alpha)}{g} = \frac{u^2 \sin(90° + 2\alpha)}{g} = \frac{u^2 \cos 2\alpha}{g}$$

For angle of projection (45° – α), horizontal range is

$$R_2 = \frac{u^2 \sin 2(45° - \alpha)}{g} = \frac{u^2 \sin(90° - 2\alpha)}{g} = \frac{u^2 \cos 2\alpha}{g}$$

$$\therefore \quad \frac{R_1}{R_2} = 1$$

5. (e) : Here, R = 10 cm
The second hand of a clock completes one rotation in 60 s.
Its angular speed is

$$\omega = \frac{2\pi \text{ rad}}{60 \text{ s}} = \frac{\pi}{30} \text{rad s}^{-1}$$

The speed of its tip is

$$v = \omega R = \frac{\pi}{30} \times 10 \text{ cm s}^{-1} \approx 1 \text{ cm s}^{-1}$$

6. (b) : Here,
Mass of the car, m = 400 kg
Retarding acceleration, a = 7.35 m s^{-2}
Let μ be coefficient of friction between the tyre of the car and the road.
As retarding force = force of friction

$$ma = \mu mg$$

$$\mu = \frac{a}{g} = \frac{7.35 \text{ m s}^{-2}}{9.8 \text{ m s}^{-2}} = 0.75$$

7. (a) : Here,
Initial velocity of hammer, u = 2 m s^{-1}
Final velocity of hammer, v = 0
Mass of hammer, m = 3 kg
Impulse imparted to the wall
= Change in momentum of hammer
= $m(v - u)$
= 3(0 – 2) = – 6 N s
|Impulse| = 6 N s

8. (c): Let A and B lift the object of mass m to the same height h in times t_A and t_B respectively. Then

$$P_A = \frac{mgh}{t_A} \text{ and } P_B = \frac{mgh}{t_B}$$

$$\therefore \quad \frac{P_A}{P_B} = \frac{t_B}{t_A} = \frac{4}{2} = \frac{2}{1}$$

9. (d) : Power of the machine gun = nK.

10. (b) : The moment of inertia is minimum along the axis EF because mass distribution is at minimum distance from EF.

11. (e) : $\vec{R}_{CM} = \frac{\sum m_i \vec{r}_i}{\sum m_i}$

Thus, the position of centre of mass of a system of particles does not depend upon the nature of particles.

12. (b) : Orbital velocity near the surface of the earth,

$$V_o = \sqrt{\frac{GM_E}{R_E}} \quad \text{... (i)}$$

Escape velocity, $V_e = \sqrt{\frac{2GM_E}{R_E}}$ ... (ii)

where M_E and R_E are the mass and radius of the earth respectively.

From eqns. (i) and (ii), we get

$$V_e = \sqrt{2}\, V_o$$

13. (a) : Time period of a satellite

$$T = 2\pi\sqrt{\frac{(R_E + h)^3}{GM_E}}$$

where M_E and R_E are the mass and radius of the earth and h is the height of the satellite.

Here, $R_E = 6400\text{ km} = 6.4 \times 10^6\text{ m}$

$M_E = 6 \times 10^{24}\text{ kg}$

$h = 35800\text{ km} = 35.8 \times 10^6\text{ m}$

$G = 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2}$

$$\therefore \quad T = 2 \times 3.14\sqrt{\frac{(6.4\times10^6 + 35.8\times10^6)^3}{6.67\times10^{-11}\times6\times10^{24}}}$$

$= 86058\text{ s} = 24\text{ hours}$

14. (e) : Let r and r' be radii of the ball of volume V and $V'(= 8V)$ respectively. Then

$$V = \frac{4}{3}\pi r^3 \text{ and } V' = \frac{4}{3}\pi r'^3$$

$$\therefore \quad \frac{V'}{V} = \left(\frac{r'}{r}\right)^3$$

$$\frac{8V}{V} = \left(\frac{r'}{r}\right)^3 \quad \text{or} \quad \frac{r'}{r} = 2 \qquad \text{... (i)}$$

According to Stokes' law

Viscous force, $F = 6\pi\eta r v$

Since η and v are same for both the balls,

$\therefore \quad F \propto r$

$$\frac{F'}{F} = \frac{r'}{r} = 2 \qquad \text{(Using (i))}$$

or $\quad F' = 2F$

15. (b) : For most of the materials, the value of the rigidity modulus (or shear modulus) is one-third of the Young's modulus.

i.e $G = \dfrac{Y}{3}$

16. (e) : Bulk modulus, $B = \dfrac{P}{(\Delta V/V)}$

$$\therefore \quad P = B\left(\frac{\Delta V}{V}\right)$$

17. (d) : The mean free path λ is the average distance covered by a molecule between two successive collisions and is given by

$$\lambda = \frac{1}{\sqrt{2}\, n\pi d^2}$$

where n is the number density and d is the diameter of the molecule.

$$\therefore \quad \lambda \propto \frac{1}{d^2}$$

18. (e) : The collision between molecules are perfectly elastic.

Except (e) all other statements are correct regarding kinetic theory of gases.

19. (b) : Here,

Heat absorbed, $\Delta Q = 2\text{ kcal} = 2 \times 10^3 \times 4.2\text{ J}$

$(\because 1\text{ cal} = 4.2\text{ J})$

$= 8.4 \times 10^3\text{ J} = 8400\text{ J}$

Work done, $\Delta W = 400\text{ J}$

According to first law of thermodynamics

Change in internal energy,

$\Delta U = \Delta Q - \Delta W$

$\Delta U = 8400\text{ J} - 400\text{ J} = 8000\text{ J} = 8 \times 10^3\text{ J} = 8\text{ kJ}$

20. (c): In SHM,

Kinetic energy, $K = \dfrac{1}{2}m\omega^2(A^2 - x^2)$

Potential energy, $U = \dfrac{1}{2}m\omega^2 x^2$

where the symbols have their usual meanings.

$$\therefore \quad \frac{K}{U} = \left[\frac{A^2 - x^2}{x^2}\right] = \left[\frac{A^2}{x^2} - 1\right]$$

At $\quad x = \dfrac{A}{2}$,

$$\frac{K}{U} = \left[\frac{A^2}{(A/2)^2} - 1\right] = \frac{3}{1}$$

21. (e) : $x = 5\cos\left(2\pi t + \dfrac{\pi}{4}\right)$ m

At $t = 1$ s,

$$x = 5\cos\left(2\pi + \frac{\pi}{4}\right) = 5\cos\frac{\pi}{4}$$

$$= \frac{5}{\sqrt{2}}\text{ m} \qquad (\because \cos(2\pi + \theta) = \cos\theta)$$

22. (c): Transverse wave propagates in solids and strings but not in liquids and gases.

Transverse wave consists of crests and troughs.
Longitudinal wave propagates in all media, solids, liquids and gases.
In a longitudinal wave, particles of the medium vibrate along the direction of propagation.
In a longitudinal wave, the higher density corresponds to compressions.

23. (c)

24. (b) : Let R be radius of the object. Then

Volume of the object, $V = \frac{4}{3}\pi R^3$

$\therefore \quad \frac{\Delta V}{V} = 3\frac{\Delta R}{R}$ ...(i)

When it is subjected to uniform pressure p, the fractional decrease in volume is

$\frac{\Delta V}{V} = \frac{p}{B}$ ...(ii)

From eqns. (i) and (ii), we get

$3\frac{\Delta R}{R} = \frac{p}{B}$ or $\frac{\Delta R}{R} = \frac{p}{3B}$

$\therefore$ Fractional decrease in radius is $p/3B$.

25. (c): When an electric dipole of dipole moment $\vec{p}$ is placed in a uniform external electric field $\vec{E}$, it experiences a torque $\vec{\tau}$ and is given by

$\vec{\tau} = \vec{p} \times \vec{E}$

In magnitude,

$\tau = pE\sin\theta$

where θ is the angle between $\vec{p}$ and $\vec{E}$.

When $\vec{p}$ is perpendicular to $\vec{E}$ *i.e.* $\theta = 90°$, then

$\tau = pE\sin 90° = pE =$ maximum.

or $\tau_{max} = pE$

26. (a) : Electric field due to a uniformly charged wire of infinite length having linear charge density λ at a point distant r from the wire is

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

i.e. $E \propto \frac{1}{r}$ or $E \propto r^{-1}$

27. (b) : According to Faraday first law of electrolysis

$m = ZIt = Z \times 4 \times 2 \times 60 = 480Z$

and $m' = Z \times 6 \times 40 = 240Z$

$\therefore \quad \frac{m'}{m} = \frac{240Z}{480Z} = \frac{1}{2}$ or $m' = \frac{m}{2}$

28. (c): Resistance of the upper arc,

$R_1 = \frac{9}{2}\ \Omega$

Resistance of the lower arc,

$R_2 = \frac{9}{2}\ \Omega$

R_1 and R_2 are in parallel.

$\therefore$ Resistance between two diametrically opposite points A and B is

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{(9/2)} + \frac{1}{(9/2)} = \frac{2}{9} + \frac{2}{9} = \frac{4}{9}$$

or $R = \frac{9}{4}\ \Omega$

29. (a) : The temperature coefficient of resistance of an alloy used for making resistors is small positive.

30. (c) : The deflection ϕ in the moving coil galvanometer is

$\phi = \left(\frac{NAB}{k}\right)I$

where

N = Number of turns in the coil

A = Area of the coil

B = Strength of magnetic field in which coil is suspended

I = Current flowing through the coil

k = Torsional constant of the spring

31. (a) : For stationary electron, $\vec{v} = 0$

$\therefore$ Force on the electron is

$\vec{F}_m = -e(\vec{v} \times \vec{B}) = 0$

32. (b) : Magnetic field at a point in the open space inside the toroid is zero.

33. (d) : Transformer is used to obtain desired ac voltage and current.

34. (b) : In an LCR series circuit,

Applied voltage, $V = \sqrt{V_R^2 + (V_C - V_L)^2}$

where V_R, V_L and V_C represent the voltage across the resistor R, inductor L and capacitor C respectively.

At resonance, $V_C = V_L$

$\therefore \quad V = V_R$

35. **(d)** : A dynamo (or generator) converts mechanical energy into electrical energy.

36. **(d)** : The electromagnetic waves detected using a thermopile and used in physical therapy are infra-red radiations.

37. **(c)** : If P is the power of the combination and P_1 and P_2 are powers of two lenses in contact, then

$$P = P_1 + P_2$$

Here, $P_1 = 15$ D, $P_2 = -3$ D

$\therefore \quad P = 15\text{ D} - 3\text{D} = 12\text{ D}$

Focal length of the combination,

$$f = \frac{1}{P} = \frac{1}{12}\text{m} = \frac{100}{12}\text{cm} = 8.33\text{ cm}$$

38. **(b)** : The speed of light in an isotropic medium depends on wavelength but it is independent on all other factors listed.

39. **(a)** : Astigmatism is corrected by using cylindrical lens.

40. **(c)** : According to Einstein's photoelectric equation,

$$eV_0 = \frac{hc}{\lambda} - \phi_0$$

or $\quad V_0 = \frac{hc}{\lambda e} - \frac{\phi_0}{e}$

where V_0 is the stopping potential, λ is the wavelength of incident light and ϕ_0 is the work function.

$\therefore \quad V_0 \propto \frac{1}{\lambda}$

As the wavelength of incident light decreases, the stopping potential increases.

The photoelectric current is independent on the wavelength of incident light.

41. **(a)** : Activity reduces from 5000 dps to 2500 dps in 150 days. Therefore, the half life of the radioactive sample is 150 days.

In 300 days (or two half lives), activity will remain $\left(\frac{1}{4}\right)^{\text{th}}$ of its initial activity.

Hence, the initial activity of the sample is

$= 4 \times 5000$ dps $= 20000$ dps

42. **(b)** : In a nuclear reactor control rods are used to absorb fast moving neutrons. They are made up of cadmium or boron.

43. **(d)** : The fusion reaction in the sun is a multi-step process in which hydrogen is burned into helium, hydrogen being the 'fuel' and helium the 'ashes'.

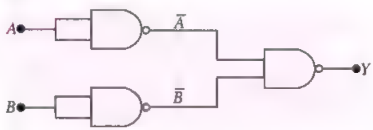
44. **(c)**: The resistivity of semiconductors is higher than metals but lower than insulators.

Except (c), all other statements are correct.

45. **(c)**: Semiconductors with band gap close to 1.5 eV are ideal materials for solar cell fabrication.

With reference to a solar cell except (c) all other statements are correct.

46. **(d)**



The output Y of the circuit is

$$Y = \overline{\bar{A} \cdot \bar{B}} = \bar{\bar{A}} + \bar{\bar{B}} = A + B$$

It is a Boolean expression of an OR gate.

Hence, three NAND gates are required to make an OR gate.

47. **(a)** : The band pass filter retains the frequencies υ_c, $\upsilon_c - \upsilon_m$ and $\upsilon_c + \upsilon_m$ and rejects the frequencies υ_m, $2\upsilon_m$ and $2\upsilon_c$.

Here, $\upsilon_c = 630$ kHz, $\upsilon_m = 6$ kHz

$\therefore$ The frequencies retained by the band pass filter are

$\upsilon_c = 630$ kHz

$\upsilon_c - \upsilon_m = (630 - 6)$ kHz $= 624$ kHz

$\upsilon_c + \upsilon_m = (630 + 6)$ kHz $= 636$ kHz

48. **(c)** : Any device that converts one form of energy into another is called a transducer.

An electrical transducer may be defined as a device that converts some physical variables (like pressure, displacement, force, temperature etc.) into corresponding variations in the electrical signal.

SOLVED PAPER 2014

Karnataka CET

1. A solenoid has length 0.4 cm, radius 1 cm and 400 turns of wire. If a current of 5 A is passed through this solenoid, what is the magnetic field inside the solenoid ?
   (a) 6.28×10^{-7} T (b) 6.28×10^{-4} T
   (c) 6.28×10^{-6} T (d) 6.28×10^{-3} T

2. A gyromagnetic ratio of the electron revolving in a circular orbit of hydrogen atom is 8.8×10^{10} C kg^{-1}. What is the mass of the electron? Given charge of the electron = 1.6×10^{-19} C.
   (a) 1.1×10^{-29} kg (b) 1×10^{-29} kg
   (c) $\frac{1}{11} \times 10^{-29}$ kg (d) 0.1×10^{-29} kg

3. What is the value of shunt resistance required to convert a galvanometer of resistance 100 Ω into an ammeter of range 1 A ?
   Given : Full scale deflection of the galvanometer is 5 mA.
   (a) 0.5 Ω (b) $\frac{5}{9.95}$ Ω
   (c) 0.05 Ω (d) $\frac{9.95}{5}$ Ω

4. A circular coil of radius 10 cm and 100 turns carries a current 1 A. What is the magnetic moment of the coil ?
   (a) 3.142 A m^2 (b) 3.142×10^4 A m^2
   (c) 3 A m^2 (d) 10^4 A m^2

5. A susceptibility of a certain magnetic material is 400. What is the class of the magnetic material ?
   (a) Ferromagnetic (b) Diamagnetic
   (c) Ferroelectric (d) Paramagnetic

6. A solenoid of inductance 2 H carries a current of 1 A. What is the magnetic energy stored in a solenoid ?
   (a) 4 J (b) 2 J (c) 5 J (d) 1 J

7. A multimeter reads a voltage of a certain A.C. source as 100 V. What is the peak value of voltage of A.C. source ?
   (a) 141.4 V (b) 200 V
   (c) 400 V (d) 100 V

8. A series *LCR* circuit contains inductance 5 mH, capacitance 2 μF and resistance 10 Ω. If a frequency A.C. source is varied, what is the frequency at which maximum power is dissipated ?
   (a) $\frac{2}{\pi} \times 10^5$ Hz (b) $\frac{10^5}{\pi}$ Hz
   (c) $\frac{5}{\pi} \times 10^3$ Hz (d) $\frac{10^{-5}}{\pi}$ Hz

9. A step down transformer has 50 turns on secondary and 1000 turns on primary winding. If a transformer is connected to 220 V 1 A A.C. source, what is output current of the transformer ?
   (a) 100 A (b) $\frac{1}{20}$ A
   (c) 2 A (d) 20 A

10. The average power dissipated in A.C. circuit is 2 watt. If a current flowing through a circuit is 2 A and impedance is 1 Ω, what is the power factor of the A.C. circuit ?
    (a) 0 (b) 0.5
    (c) $\frac{1}{\sqrt{2}}$ (d) 1

11. A plane electromagnetic wave of frequency 20 MHz travels through a space along *x* direction. If the electric field vector at a certain point in space is 6 V m^{-1}, what is the magnetic field vector at that point ?

(a) 2 T (b) 2×10^{-8} T

(c) $\frac{1}{2}$ T (d) $\frac{1}{2} \times 10^{-8}$ T

12. Two capacitors of 10 PF and 20 PF are connected to 200 V and 100 V sources respectively. If they are connected by the wire, what is the common potential of the capacitors ?
(a) 300 volt (b) 133.3 volt
(c) 400 volt (d) 150 volt

13. A physical quantity Q is found to depend on observables x, y and z, obeying relation $Q = \frac{x^3 y^2}{z}$. The percentage error in the measurements of x, y and z are 1%, 2% and 4% respectively. What is percentage error in the quantity Q ?
(a) 11% (b) 4%
(c) 1% (d) 3%

14. Which of the following is not a vector quantity ?
(a) Momentum (b) Weight
(c) Potential energy (d) Nuclear spin

15. A car moves from A to B with a speed of 30 kmph and from B to A with a speed of 20 kmph. What is the average speed of the car ?
(a) 50 kmph (b) 25 kmph
(c) 10 kmph (d) 24 kmph

16. A body starts from rest and moves with constant acceleration for t s. It travels a distance x_1 in first half of time and x_2 in next half of time, then
(a) $x_2 = 3x_1$ (b) $x_2 = x_1$
(c) $x_2 = 4x_1$ (d) $x_2 = 2x_1$

17. A person is driving a vehicle at uniform speed of 5 m s^{-1} on a level curved track of radius 5 m. The coefficient of static friction between tyres and road is 0.1. Will the person slip while taking the turn with the same speed ?
Take $g = 10$ m s^{-2}.
Choose the correct statement.
(a) A person will slip if $v^2 < 5$ m s^{-1}.
(b) A person will slip if $v^2 = 5$ m s^{-1}.
(c) A person will not slip if $v^2 > 10$ m s^{-1}.
(d) A person will slip if $v^2 > 5$ m s^{-1}.

18. A stone is thrown vertically at a speed of 30 m s^{-1} making an angle of 45° with the horizontal. What is the maximum height reached by the stone ? Take $g = 10$ m s^{-2}.
(a) 15 m (b) 30 m
(c) 10 m (d) 22.5 m

19. A force $\vec{F} = 5\hat{i} + 2\hat{j} - 5\hat{k}$ acts on a particle whose position vector is $\vec{r} = \hat{i} - 2\hat{j} + \hat{k}$. What is the torque about the origin ?
(a) $8\hat{i} - 10\hat{j} - 8\hat{k}$ (b) $8\hat{i} + 10\hat{j} + 12\hat{k}$
(c) $10\hat{i} - 10\hat{j} - \hat{k}$ (d) $8\hat{i} + 10\hat{j} - 12\hat{k}$

20. What is a period of revolution of earth satellite ? Ignore the height of satellite above the surface of earth.
Given :
(1) The value of gravitational acceleration $g = 10$ m s^{-2}.
(2) Radius of earth $R_E = 6400$ km. Take $\pi = 3.14$.
(a) 83.73 minutes (b) 85 minutes
(c) 90 minutes (d) 156 minutes

21. A period of geostationary satellite is
(a) 30 h (b) 24 h (c) 48 h (d) 12 h

22. What is the source temperature of the Carnot engine required to get 70% efficiency ?
Given sink temperature = 27°C
(a) 270°C (b) 1000°C
(c) 727°C (d) 90°C

23. A 10 kg metal block is attached to a spring of spring constant 1000 N m^{-1}. A block is displaced from equilibrium position by 10 cm and released. The maximum acceleration of the block is
(a) 200 m s^{-2} (b) 10 m s^{-2}
(c) 0.1 m s^{-2} (d) 100 m s^{-2}

24. A metallic wire of 1 m length has a mass of 10×10^{-3} kg. If a tension of 100 N is applied to a wire, what is the speed of transverse wave ?
(a) 200 m s^{-1} (b) 100 m s^{-1}
(c) 0.1 m s^{-1} (d) 10 m s^{-1}

25. A train is approaching towards a platform with a speed of 10 m s^{-1} while blowing a whistle of frequency 340 Hz. What is the frequency of

whistle heard by a stationary observer on the platform ? Given speed of sound = 340 m s^{-1}.

(a) 340 Hz (b) 330 Hz
(c) 360 Hz (d) 350 Hz

26. A rotating wheel changes angular speed from 1800 rpm to 3000 rpm in 20 s. What is the angular acceleration assuming to be uniform ?

(a) 2π rad s^{-2} (b) 60π rad s^{-2}
(c) 40π rad s^{-2} (d) 90π rad s^{-2}

27. A flow of liquid is streamline if the Reynold number is

(a) between 2000 to 3000
(b) less than 1000
(c) between 4000 to 5000
(d) greater than 1000

28. A pipe of 30 cm long and open at both the ends produces harmonics. Which harmonic mode of pipe resonates a 1.1 kHz source ? Given speed of sound in air = 330 m s^{-1}.

(a) Third harmonic (b) Fifth harmonic
(c) Second harmonic (d) Fourth harmonic

29. In anomalous expansion of water, at what temperature, the density of water is maximum?

(a) > 4°C (b) 4°C
(c) 10°C (d) < 4°C

30. An aeroplane executes a horizontal loop at a speed of 720 kmph with its wings banked at 45°. What is the radius of the loop ?
Take g = 10 m s^{-2}.

(a) 7.2 km (b) 4 km
(c) 2 km (d) 4.5 km

31. A body having a moment of inertia about its axis of rotation equal to 3 kg m^2 is rotating with angular velocity of 3 rad s^{-1}. Kinetic energy of this rotating body is same as that of a body of mass 27 kg moving with velocity v. The value of v is

(a) 2 m s^{-1} (b) 1 m s^{-1}
(c) 1.5 m s^{-1} (d) 0.5 m s^{-1}

32. A cycle tyre bursts suddenly. What is the type of this process ?

(a) Isochoric (b) Isothermal
(c) Isobaric (d) Adiabatic

33. An object is placed at 20 cm in front of a concave mirror produces three times magnified real image. What is focal length of the concave mirror ?

(a) 10 cm (b) 15 cm
(c) 7.5 cm (d) 6.6 cm

34. A focal length of a lens is 10 cm. What is power of a lens in dioptre ?

(a) 15 D (b) 0.1 D
(c) 20 D (d) 10 D

35. A microscope is having objective of focal length 1 cm and eyepiece of focal length 6 cm. If tube length is 30 cm and image is formed at the least distance of distinct vision, what is the magnification produced by the microscope ? Take D = 25 cm.

(a) 25 (b) 6 (c) 125 (d) 150

36. A fringe width of a certain interference pattern is β = 0.002 cm. What is the distance of 5^{th} dark fringe from centre ?

(a) 1.1×10^{-2} cm (b) 1×10^{-2} cm
(c) 3.28×10^{6} cm (d) 11×10^{-2} cm

37. Diameter of the objective of a telescope is 200 cm. What is the resolving power of a telescope ? Take wavelength of light = 5000 Å.

(a) 1×10^{6} (b) 6.56×10^{6}
(c) 3.28×10^{6} (d) 3.28×10^{5}

38. A polarized light of intensity I_0 is passed through another polarizer whose pass axis makes an angle of 60° with the pass axis of the former. What is the intensity of emergent polarized light from second polarizer ?

(a) $I = I_0/5$ (b) $I = I_0$
(c) $I_0/4$ (d) $I = I_0/6$

39. What is the de Broglie wavelength of the electron accelerated through a potential difference of 100 volt ?

(a) 0.1227 Å (b) 12.27 Å
(c) 0.001227 Å (d) 1.227 Å

40. The maximum kinetic energy of the photoelectrons depends only on

(a) incident angle (b) potential
(c) pressure (d) frequency

41. Which of the following spectral series of hydrogen atom is lying in visible range of electromagnetic wave ?
(a) Lyman series (b) Paschen series
(c) Balmer series (d) Pfund series

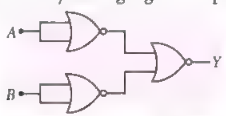
42. What is the energy of the electron revolving in third orbit expressed in eV ?
(a) 4.53 eV (b) 1.51 eV
(c) 4 eV (d) 3.4 eV

43. The relation between half life (T) and decay constant (λ) is
(a) $\lambda T = \log_e 2$ (b) $\lambda T = 1$
(c) $\lambda = \log 2T$ (d) $\lambda T = \frac{1}{2}$

44. A force between two protons is same as the force between proton and neutron. The nature of the force is
(a) electrical force
(b) weak nuclear force
(c) gravitational force
(d) strong nuclear force

45. In n type semiconductor, electrons are majority charge carriers but it does not show any negative charge. The reason is
(a) mobility of electrons is extremely small
(b) electrons are stationary
(c) atom is electrically neutral
(d) electrons neutralize with holes

46. For the given digital circuit, write the truth table and identify the logic gate it represents



(a) NAND gate (b) OR gate
(c) AND gate (d) NOR gate

47. If α-current gain of a transistor is 0.98. What is the value of β-current gain of the transistor ?
(a) 4.9 (b) 0.49
(c) 5 (d) 49

48. A tuned amplifier circuit is used to generate a carrier frequency of 2 MHz for the amplitude modulation. The value of $\sqrt{LC}$ is
(a) $\frac{1}{3\pi\times10^6}$ (b) $\frac{1}{2\pi\times10^6}$
(c) $\frac{1}{4\pi\times10^6}$ (d) $\frac{1}{2\times10^6}$

49. If a charge on the body is 1 nC, then how many electrons are present on the body ?
(a) 6.25×10^{27} (b) 1.6×10^{19}
(c) 6.25×10^{28} (d) 6.25×10^{9}

50. Two equal and opposite charges of masses m_1 and m_2 are accelerated in an uniform electric field through the same distance. What is the ratio of their accelerations if their ratio of masses is $\frac{m_1}{m_2} = 0.5$?
(a) $\frac{a_1}{a_2} = 2$ (b) $\frac{a_1}{a_2} = 0.5$
(c) $\frac{a_1}{a_2} = 3$ (d) $\frac{a_1}{a_2} = 1$

51. What is the nature of Gaussian surface involved in Gauss law of electrostatic ?
(a) Magnetic (b) Scalar
(c) Vector (d) Electrical

52. What is the electric potential at a distance of 9 cm from 3 nC ?
(a) 300 V (b) 270 V
(c) 30 V (d) 3 V

53. A voltmeter reads 4 V when connected to a parallel plate capacitor with air as a dielectric. When a dielectric slab is introduced between plates for the same configuration, voltmeter reads 2 V. What is the dielectric constant of the material ?
(a) 8 (b) 0.5
(c) 10 (d) 2

54. A spherical conductor of radius 2 cm is uniformly charged with 3 nC. What is the electric field at a distance of 3 cm from the centre of the sphere ?
(a) 3×10^4 V m^{-1} (b) 3×10^6 V m^{-1}
(c) 3×10^{-4} V m^{-1} (d) 3 V m^{-1}

55. A carbon film resistor has colour code Green Black Violet Gold. The value of the resistor is

(a) $500 \pm 5\%$ MΩ (b) 50 MΩ
(c) $500 \pm 10\%$ MΩ (d) 500 MΩ

56. Two resistors of resistances 2 Ω and 6 Ω are connected in parallel. This combination is then connected to a battery of emf 2 V and internal resistance 0.5 Ω. What is the current flowing through the battery ?

(a) $\frac{4}{17}$ A (b) 4 A
(c) 1 A (d) $\frac{4}{3}$ A

57. The equivalent resistance of two resistors connected in series is 6 Ω and their parallel equivalent resistance is $\frac{4}{3}$ Ω. What are the values of resistances ?

(a) 4 Ω, 2 Ω (b) 4 Ω, 6 Ω
(c) 6 Ω, 2 Ω (d) 8 Ω, 1 Ω

58. In a potentiometer experiment of a cell of emf 1.25 V gives balancing length of 30 cm. If the cell is replaced by another cell, balancing length is found to be 40 cm. What is the emf of second cell ?

(a) $\simeq 1.47$ V (b) $\simeq 1.57$ V
(c) $\simeq 1.37$ V (d) $\simeq 1.67$ V

59. A charged particle experiences magnetic force in the presence of magnetic field. Which of the following statement is correct ?

(a) The particle is stationary and magnetic field is perpendicular.
(b) The particle is moving and magnetic field is perpendicular to the velocity.
(c) The particle is stationary and magnetic field is parallel.
(d) The particle is moving and magnetic field is parallel to velocity.

60. If a velocity has both perpendicular and parallel components while moving through a magnetic field, what is the path followed by a charged particle ?

(a) Linear (b) Circular
(c) Helical (d) Elliptical

SOLUTIONS

1. (*) : Here,
Length, $l = 0.4$ cm $= 0.4 \times 10^{-2}$ m
Radius, $r = 1$ cm $= 10^{-2}$ m
Number of turns, $N = 400$
Current, $I = 5$ A
Number of turns per unit length is

$$n = \frac{N}{l} = \frac{400}{0.4\times10^{-2}} = 10^5 \text{ turns/m}$$

Magnetic field inside the solenoid is

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times 10^5 \times 5$$
$$= 62.8 \times 10^{-2}\text{ T} = 6.28 \times 10^{-1}\text{ T}$$

* None of the given options is correct.

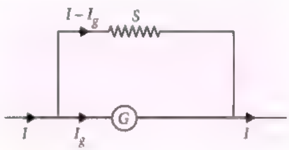
2. (c) : Gyromagnetic ratio of an electron

$$= \frac{e}{2m_e} = 8.8 \times 10^{10}\text{ C kg}^{-1}$$

∴ Mass of the electron,

$$m_e = \frac{e}{2\times8.8\times10^{10}\text{ C kg}^{-1}} = \frac{1.6\times10^{-19}\text{ C}}{2\times8.8\times10^{10}\text{ C kg}^{-1}}$$
$$= 0.0909 \times 10^{-29}\text{ kg}$$
$$= \frac{1}{11} \times 10^{-29}\text{ kg}$$

3. (b) : Here,
Resistance of galvanometer, $G = 100$ Ω
Full scale deflection current, $I_g = 5$ mA $= 5 \times 10^{-3}$ A



To convert the galvanometer into an ammeter of range 1 A, a shunt resistance of value S is connected in parallel with it such that,
$(I - I_g)S = I_gG$

$$S = \frac{I_gG}{I - I_g} = \frac{5\times10^{-3}\times100}{1-5\times10^{-3}} = \frac{5\times10^{-1}}{1-0.005}$$
$$= \frac{0.5}{0.995} = \frac{5}{9.95}\ \Omega$$

4. **(a) :** Here,
Radius, $r = 10$ cm $= 10 \times 10^{-2}$ m
Number of turns, $N = 100$
Current, $I = 1$ A
Area of the coil, $A = \pi r^2$
Magnetic moment of the coil,
$M = NIA = NI\pi r^2$
$= 100 \times 1 \times 3.142 \times (10 \times 10^{-2})^2$ A m^2
$= 3.142$ A m^2

5. **(a) :** As susceptibility is large and positive, the given material is ferromagnetic.

6. **(d) :** Here,
Inductance, $L = 2$ H, current, $I = 1$ A
Magnetic energy stored in the solenoid is
$U = \frac{1}{2}LI^2 = \frac{1}{2} \times 2 \times (1)^2 = 1$ J

7. **(a) :** The multimeter reads the rms value of A.C. source.
$\therefore \quad V_{rms} = 100$ V
The peak voltage of the source is
$V_0 = \sqrt{2}V_{rms} = \sqrt{2} \times 100\text{ V} = 141.4\text{ V}$

8. **(c) :** Maximum power is dissipated at resonant frequency.
Resonant frequency, $\upsilon_r = \frac{1}{2\pi\sqrt{LC}}$
Here, $L = 5$ mH $= 5 \times 10^{-3}$ H
$C = 2$ μF $= 2 \times 10^{-6}$ F
$$\therefore \quad \upsilon_r = \frac{1}{2\pi\sqrt{5\times10^{-3}\times2\times10^{-6}}} = \frac{1}{2\pi\sqrt{10^{-8}}}$$
$$= \frac{10^4}{2\pi} = \frac{5}{\pi} \times 10^3 \text{ Hz}$$

9. **(d):** As $\frac{I_p}{I_s} = \frac{N_s}{N_p}$
where subscripts 'p' and 's' represent primary and secondary.
$$\therefore \quad I_s = \left(\frac{N_p}{N_s}\right)I_p$$
Here,
$I_p = 1$ A, $N_p = 1000$, $N_s = 50$
$$\therefore \quad I_s = \left(\frac{1000}{50}\right)(1\text{ A}) = 20\text{ A}$$
Hence the output current of the transformer is 20 A.

10. **(b):** Average power dissipated in A.C. circuit is
$P = I^2Z\cos\phi$
where $\cos\phi$ is the power factor of the circuit.
$$\therefore \quad \cos\phi = \frac{P}{I^2Z}$$
Here, $P = 2$ W, $I = 2$ A, $Z = 1$ Ω
$$\therefore \quad \cos\phi = \frac{2}{(2)^2(1)} = \frac{1}{2} = 0.5$$

11. **(b):** The magnitude of magnetic field is
$$B = \frac{E}{c} = \frac{6\text{ V m}^{-1}}{3\times10^8\text{ m s}^{-1}} = 2 \times 10^{-8}\text{ T}$$

12. **(b):** Common potential,
$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$
Here, $C_1 = 10$ PF, $V_1 = 200$ V
$C_2 = 20$ PF, $V_2 = 100$ V
$$\therefore \quad V = \frac{10\times200+20\times100}{10+20} = \frac{4000}{30}\text{ V} = 133.3\text{ V}$$

13. **(a) :** $Q = \frac{x^3y^2}{z}$
The percentage error in the quantity Q is
$$\frac{\Delta Q}{Q}\times100 = \left(3\frac{\Delta x}{x} + 2\frac{\Delta y}{y} + \frac{\Delta z}{z}\right)\times100$$
$$= 3\left(\frac{\Delta x}{x}\times100\right) + 2\left(\frac{\Delta y}{y}\times100\right) + \frac{\Delta z}{z}\times100$$
$= 3 \times 1\% + 2 \times 2\% + 4\%$
$= 11\%$

14. **(c) :** Among the given quantities potential energy is a scalar quantity whereas all others are vector quantities.

15. **(d):** Let S be distance between A and B.
Let t_1 be time taken by the car to move from A to B with speed v_1 and t_2 be time taken by the car to move from B to A with speed v_2. Then
$$t_1 = \frac{S}{v_1} \text{ and } t_2 = \frac{S}{v_2}$$
Average speed of the car
$$v_{av} = \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{2S}{t_1 + t_2}$$

$$= \frac{2S}{\frac{S}{v_1}+\frac{S}{v_2}} = \frac{2v_1v_2}{v_1+v_2}$$

Here, $v_1 = 30$ kmph, $v_2 = 20$ kmph

$$\therefore \quad v_{av} = \frac{2\times 30\times 20}{30+20} = 24 \text{ kmph}$$

16. (a) : As the body starts from rest,

$\therefore \quad u = 0$

Let a be constant acceleration of the body.
Distance travelled by the body in $(t/2)$ s is

$$x_1 = \frac{1}{2}a\left(\frac{t}{2}\right)^2 = \frac{1}{8}at^2 \quad \ldots\text{(i)}$$

Distance travelled by the body in t s is

$$x_1 + x_2 = \frac{1}{2}at^2 = 4x_1 \quad \text{(Using (i))}$$

$\therefore \quad x_2 = 4x_1 - x_1 = 3x_1$

17. (d) : The person will not slip if

$v^2 \le \mu_s Rg$

Here, $\mu_s = 0.1$, $R = 5$ m, $g = 10$ m s^{-2}

$\therefore \quad \mu_s Rg = 0.1 \times 5 \text{ m} \times 10 \text{ m s}^{-2} = 5\text{m}^2 \text{ s}^{-2}$

or $\quad v^2 \le 5 \text{ m}^2 \text{ s}^{-2}$

Therefore the person will slip if $v^2 > 5\text{m}^2 \text{ s}^{-2}$.

Note : In the question paper the unit of v^2 is given to be m s^{-1}. But it is wrong. It is a unit of v not v^2. The correct unit of v^2 is m^2 s^{-2}.

18. (d) : Maximum height reached by the stone is

$$H_{max} = \frac{u^2\sin^2\theta}{2g}$$

Here, $u = 30$ m s^{-1}, $\theta = 45°$, $g = 10$ m s^{-2}

$$\therefore \quad H_{max} = \frac{(30)^2\sin^2 45°}{2\times 10} = \frac{30\times 30\times\left(\frac{1}{\sqrt{2}}\right)^2}{2\times 10}$$

$$= \frac{45}{2} = 22.5 \text{ m}$$

19. (b) : Here, $\vec{r} = \hat{i} - 2\hat{j} + \hat{k}$

$\vec{F} = 5\hat{i} + 2\hat{j} - 5\hat{k}$

Torque, $\vec{\tau} = \vec{r}\times\vec{F}$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -2 & 1 \\ 5 & 2 & -5 \end{vmatrix}$$

$$= \hat{i}(10-2) - \hat{j}(-5-5) + \hat{k}(2-(-10))$$

$$= 8\hat{i} + 10\hat{j} + 12\hat{k}$$

20. (a) : Period of revolution of earth satellite is

$$T = 2\pi\sqrt{\frac{(R_E+h)^3}{gR_E^2}}$$

Neglecting h, then

$$T = 2\pi\sqrt{\frac{R_E}{g}}$$

Substituting the given values, we get

$$T = 2\times 3.14\sqrt{\frac{6400\times 10^3}{10}} \text{ s}$$

$$= 5024 \text{ s} = \frac{5024}{60} \text{ minutes}$$

$$= 83.73 \text{ minutes}$$

21. (b) : The period of geostationary satellite is same as that of the period of rotation of the earth about its own axis *i.e.*, 24 h.

22. (c) : Efficiency of the Carnot engine,

$$\eta = 1 - \frac{T_2}{T_1}$$

where T_1 and T_2 are the temperatures of source and sink respectively.

Here, $\quad \eta = 70\% = \frac{70}{100} = 0.7$

$T_1 = 27°\text{C} = (27 + 273) \text{ K} = 300 \text{ K}$

$$\therefore \quad 0.7 = 1 - \frac{300}{T_1}$$

$$\frac{300}{T_1} = 1 - 0.7 = 0.3$$

$$T_1 = \frac{300}{0.3} \text{ K} = 1000 \text{ K} = (1000 - 273)°\text{C}$$

$$= 727°\text{C}$$

23. (b) : Here,

Amplitude, $A = 10$ cm $= 0.1$ m

Spring constant, $k = 1000$ N m^{-1}

Mass, $m = 10$ kg

Maximum acceleration of the block is

$$a_{max} = \omega^2 A = \frac{kA}{m} \quad \left(\because \omega = \sqrt{\frac{k}{m}}\right)$$

$$= \frac{1000 \text{ N m}^{-1}\times 0.1 \text{ m}}{10 \text{ kg}}$$

$$= 10 \text{ m s}^{-2}$$

24. **(b) :** Here,

Mass per unit length of the wire,

$$\mu = \frac{10\times10^{-3}\,\text{kg}}{1\,\text{m}} = 10 \times 10^{-3}\ \text{kg m}^{-1}$$

Tension, $T = 100$ N

The speed of transverse wave on the wire is

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{100\ \text{N}}{10\times10^{-3}\,\text{kg m}^{-1}}} = 100\ \text{m s}^{-1}$$

25. **(d) :** Here,

Speed of train, $v_T = 10$ m s^{-1}

Speed of sound, $v = 340$ m s^{-1}

Frequency of whistle, $\upsilon = 340$ Hz

The frequency of whistle heard by the stationary observer on the platform is

$$\upsilon' = \upsilon\left(\frac{v}{v - v_T}\right) = 340\left(\frac{340}{340-10}\right)$$

$$= 340\left(\frac{340}{340-10}\right) = 350\ \text{Hz}$$

26. **(a) :** Here,

Initial angular speed of the wheel,

$$\omega_0 = 1800 \times \frac{2\pi}{60}\ \text{rad s}^{-1} = 60\pi\ \text{rad s}^{-1}$$

Final angular speed of the wheel,

$$\omega = 3000 \times \frac{2\pi}{60}\ \text{rad s}^{-1} = 100\pi\ \text{rad s}^{-1}$$

Time during which this change of speed takes place, $t = 20$ s

Let α be angular acceleration of the wheel.

As $\omega = \omega_0 + \alpha t$

$$\therefore \quad \alpha = \frac{\omega - \omega_0}{t} = \frac{100\pi - 60\pi}{20}\ \text{rad s}^{-2}$$

$$= 2\pi\ \text{rad s}^{-2}$$

27. **(b):** If Reynold number is less than 1000, the flow is streamline.

If Reynold number is greater than 2000, the flow is turbulent.

If Reynold number lies between 1000 and 2000, the flow becomes unsteady.

28. **(c) :** Here,

Speed of sound, $v = 330$ m s^{-1}

Length of pipe, $L = 30$ cm $= 30 \times 10^{-2}$ m

In an open pipe (open at both ends), the frequency of its n^{th} harmonic is

$$\upsilon_n = \frac{nv}{2L} \text{ where } n = 1, 2, 3, \ldots\ldots$$

$$\therefore \quad n = \frac{2L\upsilon_n}{v}$$

Let n^{th} harmonic of open pipe resonate with 1.1 kHz source.

i.e., $\upsilon_n = 1.1$ kHz $= 1.1 \times 10^3$ Hz

$$\therefore \quad n = \frac{2\times30\times10^{-2}\times1.1\times10^3}{330} = 2$$

29. **(b) :** Water has maximum density at 4°C.

30. **(b) :** Here,

Speed of the aeroplane, $v = 720$ kmph

$$v = 720 \times \frac{5}{18}\ \text{m s}^{-1} = 200\ \text{m s}^{-1}$$

Angle of banking, $\theta = 45°$

Let R be the radius of the loop.

As $\tan\theta = \dfrac{v^2}{Rg}$

$$\therefore \quad R = \frac{v^2}{g\tan\theta} = \frac{(200)^2}{10\times\tan 45^\circ} = \frac{4\times10^4}{10\times1}$$

$$= 4000\ \text{m} = 4\ \text{km}$$

31. **(b):** Here,

Moment of inertia of the body about its axis of rotation, $I = 3$ kg m^2

Angular velocity of rotation, $\omega = 3$ rad s^{-1}

Kinetic energy of rotation of the body is

$$K_R = \frac{1}{2}I\omega^2$$

Kinetic energy of body of mass $m(= 27$ kg) moving with velocity v is

$$K_T = \frac{1}{2}mv^2$$

As per question, $K_R = K_T$

$$\therefore \quad \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2$$

$$\frac{1}{2} \times 3 \times 3^2 = \frac{1}{2} \times 27 \times v^2$$

or $\quad v^2 = 1$ or $v = 1$ m s^{-1}

32. **(d):** Sudden bursting of the cycle tyre is an adiabatic process.

33. **(b):** As image is real

$\therefore$ Magnification, $m = -\dfrac{v}{u} = -3$ or $v = 3u$

Here, $u = -20$ cm

$\therefore \quad v = -60$ cm

According to mirror formula

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$$

$$\frac{1}{f}=\frac{1}{-60}+\frac{1}{-20}=-\frac{4}{60}$$

$f = -15$ cm

$|f| = 15$ cm

34. (d): Power of a lens,

$$P\text{ (in dioptre)}=\frac{1}{\text{Focal length } f\text{ (in m)}}=\frac{100}{f\text{ (in cm)}}$$

$$\therefore \qquad P=\frac{100}{10}=10\text{ D}$$

35. (d): Here,

Focal length of objective, $f_o = 1$ cm

Focal length of eyepiece, $f_e = 6$ cm

Least distance of distinct vision, $D = 25$ cm

Tube length, $L = 30$ cm

When the image is formed at the least distance of distinct vision, the magnification is

$$m=\frac{L}{f_o}\left(1+\frac{D}{f_e}\right)=\frac{30}{1}\left(1+\frac{25}{6}\right)$$

$$= 155 \approx 150$$

36. (*): Here,

Fringe width, $\beta = 0.002$ cm $= 2 \times 10^{-3}$ cm

Distance of n^{th} dark fringe from centre

$$x_n=\left(n-\frac{1}{2}\right)\frac{\lambda D}{d} \quad \text{where } n = 1, 2, 3, \ldots$$

As $\quad \beta=\dfrac{\lambda D}{d}$

$$\therefore \quad x_n=\left(n-\frac{1}{2}\right)\beta$$

For 5^{th} dark fringe, $n = 5$

$$\therefore \quad x_5=\left(5-\frac{1}{2}\right)\beta=\frac{9}{2}\beta=\frac{9}{2}\times 2\times 10^{-3}\text{ cm}$$

$$= 9 \times 10^{-3}\text{ cm}$$

* None of the given options is correct.

37. (c) : Here,

Diameter of the objective,

$D = 200$ cm $= 200 \times 10^{-2}$ m $= 2$ m

Wavelength of light,

$\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m $= 5 \times 10^{-7}$ m

Resolving power of a telescope $=\dfrac{D}{1.22\lambda}$

$$=\frac{2}{1.22\times 5\times 10^{-7}}=\frac{4}{1.22}\times 10^{6}$$

$$= 3.28 \times 10^6$$

38. (c) : According to Malus' law, the intensity of emergent polarized light from second polarizer is

$$I = I_0\cos^2\theta$$

where θ is the angle between pass axes of two polarizers and I_0 is the intensity of polarized light after passing through the first polarizer.

Here, $\theta = 60°$

$$\therefore \quad I = I_0\cos^2 60° = I_0\left(\frac{1}{2}\right)^2=\frac{I_0}{4}$$

39. (d): de Broglie wavelength of the electron accelerated through a potential difference of V volt is

$$\lambda=\frac{12.27}{\sqrt{V}}\text{ Å}$$

For $V = 100$ volt

$$\lambda=\frac{12.27}{\sqrt{100}}\text{ Å} = 1.227\text{ Å}$$

40. (d)

41. (c) : The Balmer series lies in the visible region.

The Lyman series is in the ultraviolet region, and Paschen and Pfund series are in the infrared region.

42. (b): Energy of the electron in n^{th} orbit is

$$E_n=-\frac{13.6}{n^2}\text{ eV}$$

For third orbit, $n = 3$

$$\therefore \quad E_3=-\frac{13.6}{3^2}\text{ eV} = -1.51\text{ eV}$$

43. (a) : The relation between half life (T) and decay constant (λ) is

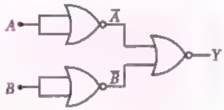
$$T=\frac{\ln 2}{\lambda}=\frac{\log_e 2}{\lambda}$$

or $\quad T\lambda = \log_e 2$

44. (d): The strong nuclear force binds protons and neutrons in a nucleus. It acts equally between proton-proton, neutron-neutron and proton-neutron.

45. (c) : The atom is electrically neutral.

46. (c) :



The output Y of the circuit is

$Y = \overline{\overline{A} + \overline{B}} = \overline{\overline{A}} \cdot \overline{\overline{B}} = A \cdot B$

It is a Boolean expression for AND gate.

Hence the given digital circuit represents the AND gate.

47. (d): The relation between α and β is

$$\beta = \frac{\alpha}{1-\alpha}$$

Here, $\alpha = 0.98$

$$\therefore \quad \beta = \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = 49$$

48. (c) : $\upsilon = \dfrac{1}{2\pi\sqrt{LC}}$

$$\therefore \quad \sqrt{LC} = \frac{1}{2\pi\upsilon}$$

Here, $\upsilon = 2$ MHz $= 2 \times 10^6$ Hz

$$\therefore \quad \sqrt{LC} = \frac{1}{2\pi \times 2 \times 10^6} = \frac{1}{4\pi \times 10^6}$$

49. (d): Charge on the body is

$q = ne$

$\therefore$ No. of electrons present on the body is

$$n = \frac{q}{e} = \frac{1 \times 10^{-9}\,\text{C}}{1.6 \times 10^{-19}\,\text{C}} = 6.25 \times 10^9$$

50. (a) : Force is same in magnitude for both.

$\therefore \quad m_1 a_1 = m_2 a_2$

$$\frac{a_1}{a_2} = \frac{m_2}{m_1} = \frac{1}{0.5} = 2$$

51. (c)

52. (a) : Electric potential due to a point charge Q at a distance r from it, is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

Here, $Q = 3$ nC $= 3 \times 10^{-9}$ C

$r = 9$ cm $= 9 \times 10^{-2}$ m

$$\therefore \quad V = \frac{9 \times 10^9 \times 3 \times 10^{-9}}{9 \times 10^{-2}} = 300 \text{ V}$$

53. (d): Let V_0 be the potential difference between the plates of an air filled parallel plate capacitor.

When a dielectric slab is introduced between its plates, its potential difference will become

$$V = \frac{V_0}{K}$$

where K is the dielectric constant of the slab.

$$\therefore \quad K = \frac{V_0}{V}$$

Here, $V_0 = 4$ V, $V = 2$ V

$$\therefore \quad K = \frac{4\text{ V}}{2\text{ V}} = 2$$

54. (a) : Here,

$Q = 3$ nC $= 3 \times 10^{-9}$ C

$R = 2$ cm $= 2 \times 10^{-2}$ m

At a point 3 cm from the centre,

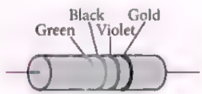
i.e., $r = 3$ cm $= 3 \times 10^{-2}$ m

$\therefore$ Electric field,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} = \frac{9 \times 10^9 \times 3 \times 10^{-9}}{(3 \times 10^{-2})^2}$$

$$= 3 \times 10^4 \text{ V m}^{-1}$$

55. (a) :



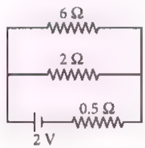
The number assigned to green, black and violet are 5, 0 and 7. For gold, tolerance is 5%.

$\therefore$ Resistance value of the given resistor is

$R = 50 \times 10^7\ \Omega \pm 5\%$

$= 500$ M$\Omega \pm 5\%$

56. (c) :



Resistors 2 Ω and 6 Ω are connected in parallel. Their equivalent resistance is

$$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{6} = \frac{4}{6} = \frac{2}{3}$$

$$R_p = \frac{3}{2}\ \Omega = 1.5\ \Omega$$

Current flowing through the battery is

$$I = \frac{\varepsilon}{R_p + r} = \frac{2\text{ V}}{1.5\,\Omega + 0.5\,\Omega} = 1\text{ A}$$

57. **(a)** : Let R_1 and R_2 be two resistors.

When they are connected in series, their equivalent resistance is

$$R_s = R_1 + R_2 = 6\,\Omega \quad \text{...(i)}$$

When they are connected in parallel, their equivalent resistance is

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{4}{3}\,\Omega \quad \text{...(ii)}$$

On solving eqns. (i) and (ii), we get

$R_1 = 2\,\Omega$ and $R_2 = 4\,\Omega$

58. **(d)**: As $\dfrac{\varepsilon_1}{\varepsilon_2} = \dfrac{l_1}{l_2}$

where ε_1 and ε_2 are the emfs of two cells and l_1 and l_2 are the corresponding balancing lengths of the potentiometer wire.

$$\therefore \quad \varepsilon_2 = \frac{l_2}{l_1}\varepsilon_1$$

Here, $\varepsilon_1 = 1.25$ V, $l_1 = 30$ cm, $l_2 = 40$ cm

$$\therefore \quad \varepsilon_2 = \frac{40}{30} \times 1.25 \approx 1.67\text{ V}$$

59. **(b)**: Magnetic force on the charged particle q is

$\vec{F}_m = q(\vec{v} \times \vec{B})$ or $F_m = qvB\sin\theta$

where θ is the angle between $\vec{v}$ and $\vec{B}$.

Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force.

60. **(c)** : Due to perpendicular component the charged particle will describe a circular path and due to parallel component it will move linear distance along the magnetic field. Hence, it will follow a helical path.

Thought Provoking Problems

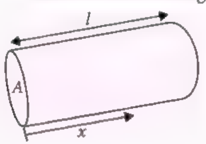
Current Electricity

By : Prof. Rajinder Singh Randhawa*

1. A conductor has a temperature independent resistance R and total heat capacity C. At the moment $t = 0$, it is connected to a dc voltage V. Find the time dependence of the conductor's temperature T assuming the thermal power dissipated into surrounding space to vary as $Q = K(T - T_0)$ where K is a constant, T_0 is the environmental temperature (equal to conductor's temperature at the initial moment).

2. Two conductors with temperature coefficients of resistance α_1 and α_2 have resistances R_{01} and R_{02} at 0°C. Find the temperature coefficient of a circuit consisting of these conductors if they are connected in series and in parallel.

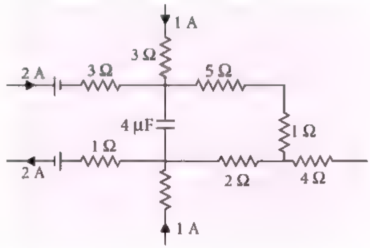
3. The cross-section area and length of a cylindrical conductor are A and l, respectively. The specific conductance varies as $\sigma(x) = \sigma_0 \dfrac{l}{\sqrt{x}}$, where x is the distance along the axis of the cylinder from one of its ends as shown in figure.



(a) Compute the resistance of the system along the cylindrical axis.

(b) Compute the current density if the potential drop along the cylinder is V_0. What is the electric field at each point in the cylinder?

4. A part of circuit in steady state along with the current flowing in the branches, with value of each resistance is shown in figure.



Calculate the energy stored in the capacitor.

5. How long does it take for current to decay to half of its value, while charging series RC circuit? We can consider this time as half life of the current in a charging series RC circuit.

6. (a) Calculate the power absorbed by a charging capacitor in the series RC circuit as a function of time.

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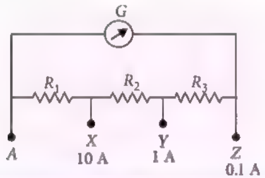
(b) Integrate $P(t)$ from $t = 0$ to $t = \infty$ to show that the energy stored in the capacitor is $\frac{1}{2}CV_0^2$, when it is fully charged.

7. The galvanometer shown in figure has resistance 50 Ω and current required for full scale deflection is 1 mA. Find the resistances R_1, R_2 and R_3 required to convert it into ammeter having ranges as indicated.



SOLUTIONS

1. Power $\left(\frac{V^2}{R}\right)$ generated in the resistance is being lost in the environment and utilized in raising the temperature of the conductor.

Hence, $\frac{V^2}{R} = \underbrace{K(T-T_0)}_{\text{Heat lost to the environment}} + \underbrace{C\left(\frac{dT}{dt}\right)}_{\text{Heat absorbed by conductor}}$

$$C\left(\frac{dT}{dt}\right) = \frac{V^2}{R} - K(T-T_0)$$

or $\int_0^t \frac{dt}{C} = \int_{T_0}^{T} \frac{dT}{\frac{V^2}{R} - K(T-T_0)}$

Solving we get, $T = T_0 + \frac{V^2}{KR}(1 - e^{-Kt/C})$

2. Here, $R_{t1} = R_{01}(1 + \alpha_1 t)$, $R_{t2} = R_{02}(1 + \alpha_2 t)$
In series, the resistance of the circuit is
$Rt_s = R_{01} + R_{02} + \alpha_1 R_{01}t + \alpha_2 R_{02}t$.
Also, $R_{ts} = R_{0s}(1 + \alpha' t)$, where $R_{0s} = R_{01} + R_{02}$ and α' is the required temperature coefficient.
Therefore,

$$\alpha' = \frac{R_{01}\alpha_1 + R_{02}\alpha_2}{R_{01} + R_{02}}$$

In parallel, $R_{tp} = \frac{R_{01}R_{02}(1+\alpha_1 t)(1+\alpha_2 t)}{R_{01}(1+\alpha_1 t) + R_{02}(1+\alpha_2 t)}$

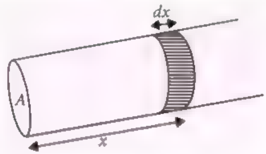
Also, $R_{tp} = R_{0p}(1 + \alpha'' t)$

where, $R_{0p} = \frac{R_{01}R_{02}}{R_{01} + R_{02}}$

and α'' is the required temperature coefficient in parallel.
Eliminating the terms proportional to the products of the temperature coefficients as being small, we get

$$\alpha'' = \frac{R_{02}\alpha_1 + R_{01}\alpha_2}{R_{t1} + R_{t2}}$$

3. Consider elementary portion dx on the cylinder.



(a) $dR = \frac{1}{\sigma(x)}\frac{dx}{A} = \frac{\sqrt{x}\,dx}{Al\sigma_0}$

Total resistance,

$$R = \int_0^l dR = \frac{1}{Al\sigma_0}\int_0^l \sqrt{x}\,dx = \frac{2\sqrt{l}}{3A\sigma_0}$$

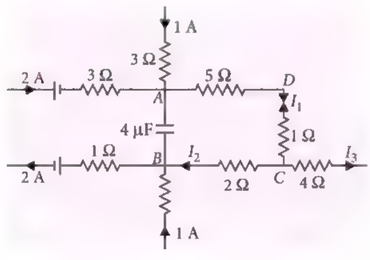
(b) From Ohm's law, $I = \frac{V_0}{R} = \frac{3A\sigma_0 V_0}{2\sqrt{l}}$

∴ Current density, $J = \frac{I}{A} = \frac{3\sigma_0 V_0}{2\sqrt{l}}$

The electric field in the cylinder may be found by using ohm's law,

$$E(x) = \frac{J}{\sigma(x)} = \frac{J}{\sigma_0 \frac{l}{\sqrt{x}}} = \frac{3V_0\sqrt{x}}{2l^{3/2}}$$

4.



Applying KCL at junctions A and B respectively, we have,

$2 + 1 - I_1 = 0$ *i.e.* $I_1 = 3$ A

and $I_2 + 1 - 2 = 0$ *i.e.* $I_2 = 1$ A.

Let potential at points A and B be V_A and V_B respectively.

From figure, $V_A - 3 \times 5 - 3 \times 1 - 1 \times 2 = V_B$

or $V_A - V_B = V = 20$ V

So, energy stored in the capacitor,

$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times (4 \times 10^{-6}) \times (20)^2 = 8 \times 10^{-4} \text{ J}$$

5. The current in a charging series RC circuit is given by

$I = I_0 e^{-t/RC}$

When the current is halved, then

$$\frac{I_0}{2} = I_0 e^{-t/RC} \quad \text{or} \quad \frac{1}{2} = e^{-t/RC}$$

Taking the natural log on both sides, we get

$\ln 1 - \ln 2 = -t/RC,$

On solving for t, we've

$t = RC \ln 2 = \tau \ln 2 = 0.693\,\tau$

where $\tau = RC$ is time constant of the circuit.

6. (a) Rate at which energy is dissipated in the resistor is

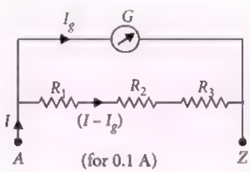
$$P(t) = I^2 R = \left(\frac{V_0}{R} e^{-t/RC}\right)^2 R = \frac{V_0^2}{R} e^{-2t/RC}$$

(b) $$U = \int_0^\infty P(t)dt = \int_0^\infty \frac{V_0^2}{R} e^{-2t/RC} dt = \frac{-V_0^2 C}{2}(e^{-2t/RC})_0^\infty$$

$$= \frac{-V_0^2 C}{2}(0 - 1) = \frac{1}{2} C V_0^2$$

7. Here, $G = 50\ \Omega$, $I_g = 1\text{mA} = 10^{-3}\text{A}$.

For the range 0.1 A, R_1, R_2 and R_3 are in series combination.

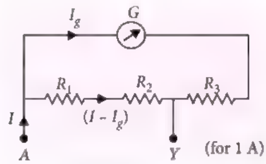


$\therefore \quad I_g G = (I - I_g)(R_1 + R_2 + R_3)$

Hence,

$$R_1 + R_2 + R_3 = \frac{I_g G}{I - I_g} = \frac{10^{-3} \times 50}{0.1 - 10^{-3}} = \frac{50}{99}\,\Omega \quad \text{...(i)}$$

For range 1 A, $(R_1 + R_2)$ is in parallel to $(G + R_3)$

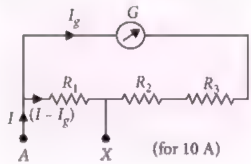


$\therefore \quad I_g(G + R_3) = (I - I_g)(R_1 + R_2)$

or $\quad I_g(G + R_1 + R_2 + R_3) = I(R_1 + R_2)$

$$\Rightarrow \quad R_1 + R_2 = 10^{-3}\left[\frac{50 + \frac{50}{99}}{1}\right] = \frac{5}{99}\,\Omega \quad \text{...(ii)}$$

For range 10 A, R_1 is in parallel to $(G + R_2 + R_3)$.



So, $I_g(G + R_2 + R_3) = (I - I_g)R_1$

$$R_1 = \frac{I_g(G + R_1 + R_2 + R_3)}{I}$$

$$= \frac{10^{-3}\left(50 + \frac{50}{99}\right)}{10} = \frac{5}{990}\ \Omega$$

or $$R_1 = \frac{1}{198}\,\Omega \quad \text{...(iii)}$$

So, $$R_2 = \frac{5}{99} - \frac{5}{990} = \frac{1}{22}\,\Omega$$

and $$R_3 = \frac{50}{99} - (R_1 + R_2)$$

$$R_3 = \frac{50}{99} - \frac{5}{99} = \frac{45}{99} = \frac{5}{11}\,\Omega$$

Hence,

$$R_1 = \frac{1}{198}\,\Omega,\ R_2 = \frac{1}{22}\,\Omega \text{ and } R_3 = \frac{5}{11}\,\Omega$$

NCERT Xtract

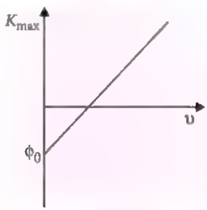
New

Questions for Medical/ Engineering Entrance Exams

Dual Nature of Radiation and Matter

1. For what kinetic energy of proton, will the associated de Broglie wavelength be 16.5 nm? (Given $m_p = 1.675 \times 10^{-27}$ kg, $h = 6.63 \times 10^{-34}$ J s)
(a) 5.2×10^{-34} J (b) 5.2×10^{-20} J
(c) 4.8×10^{-25} J (d) 4.8×10^{-30} J

2. The given graph shows the variation of frequency of incident radiation with the maximum kinetic energy of the electrons emitted from the surface of photo sensitive material.



Which of the following statements is/are true about the graph?
(a) Slope of the graph gives the value of Planck's constant.
(b) Intercept on the negative K_{max} axis gives the value of work function.
(c) The maximum kinetic energy of emitted electrons depends on the intensity of incident radiation
(d) Both (a) and (b)

3. In photoelectric effect, the photo-current
(a) depends both on intensity and frequency of the incident light.
(b) does not depend on the frequency of incident light but depends on the intensity of the incident light.
(c) decreases with increase in frequency of incident light.
(d) increases with increase in frequency of incident light.

4. Radiations of frequencies υ_1 and υ_2 are made to fall in turn on a photosensitive surface. The stopping potentials required for stopping the most energetic emitted photo electrons in the two cases are V_1 and V_2 respectively. Then the value of Planck's constant in terms of these parameters is
(a) $\frac{e(V_1+V_2)}{\upsilon_1+\upsilon_2}$ (b) $\frac{e(V_1-V_2)}{\upsilon_1+\upsilon_2}$
(c) $\frac{e(V_2-V_1)}{\upsilon_2-\upsilon_1}$ (d) $\frac{V_1-V_2}{e(\upsilon_2-\upsilon_1)}$

5. A particle moves in a closed orbit around the origin, due to a force which is directed towards the origin. The de Broglie wavelength of the particle varies cyclically between two values λ_1 and λ_2 with $\lambda_1 > \lambda_2$. Which of the following statements is true?

(a) The particle could be moving in a circular orbit with origin as centre.
(b) The particle could be moving in an elliptic orbit with origin as its focus.
(c) When the de Broglie wavelength is λ_1, the particle is nearer the origin than when its value is λ_2.
(d) Both (a) and (c)

6. A particle of mass m at rest decays into two particles of masses m_1 and m_2 having non-zero velocities. The ratio of de Broglie wavelengths of the two particle is
(a) 1 : 1 (b) 1 : 2 (b) 2 : 1 (d) 1 : 4

7. Photoelectric effect supports quantum nature of light because
(a) there is minimum frequency of light below which no photoelectrons are emitted
(b) the maximum kinetic energy of photo electrons depends only on the frequency of light and not on its intensity.
(c) even when the metal surface is faintly illuminated, the photoelectrons leave the surface immediately.
(d) all of these

8. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5 V. The incident radiation lies in (Take hc = 1240 eV nm)
(a) ultraviolet region (b) infrared region
(c) visible region (d) X-ray region

9. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectrons emission from this substance is approximately
(a) 540 nm (b) 400 nm
(c) 310 nm (d) 220 nm

10. The collector plate in an experiment on photoelectric effect is kept vertically above the emitter plate. Light source is put on and a saturation photoelectric current is recorded. An electric field is switched on which has a vertically downward direction, then
(a) the photoelectric current will increase
(b) the kinetic energy of the electrons will increase
(c) the threshold wavelength will increase
(d) the stopping potential will decrease.

11. If K_1 and K_2 are maximum kinetic energies of photoelectrons emitted when lights of wavelength λ_1 and λ_2 respectively incident on a metallic surface. If $\lambda_1 = 3\lambda_2$, then
(a) $K_1 > \left(\frac{K_2}{3}\right)$ (b) $K_1 < \left(\frac{K_2}{3}\right)$
(c) $K_1 = 3K_2$ (d) $K_2 = 3K_1$

12. An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photoelectrons emitted from this surface have the de Broglie wavelength λ', then
(a) $\lambda = \frac{mc}{h}\lambda'^2$ (b) $\lambda = \frac{mc}{2h}\lambda'$
(c) $\lambda = \frac{2mc}{h}\lambda'^2$ (d) $\lambda = \frac{mc}{2h}\lambda'^2$

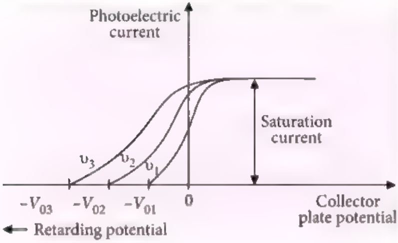
13. If the kinetic energy of the particle is increased by 16 times, the percentage change in the de Broglie wavelength of the particle is
(a) 25% (b) 75% (c) 60% (d) 50%

14. Light of frequency 7.21×10^{14} Hz is incident on a metal surface. Electrons with maximum speed of 6×10^5 m s^{-1} are ejected from the surface. The threshold frequency for photoemission of electrons is
(a) 2×10^{12} Hz (b) 2×10^{14} Hz
(c) 5×10^{12} Hz (d) 5×10^{14} Hz

15. When a monochromatic point source of light is at distance of 0.2 m from a photoelectric cell, the cut off voltage and the saturation current are respectively 0.6 V and 18 mA. If the same source is placed 0.6 m away from the photoelectric cell, then
(a) the stopping potential will be 0.2 V
(b) the stopping potential will be 0.6 V
(c) the saturation current will be 4 mA
(d) both (a) and (c)

16. A proton has kinetic energy K = 100 eV which is equal to that of a photon. The wavelength of photon is λ_2 and that of proton is λ_1. The ratio $\frac{\lambda_2}{\lambda_1}$ is proportional to
(a) K^2 (b) $K^{1/2}$ (c) K^{-1} (d) $K^{-1/2}$

17. Variation of photo electric current with collector plate potential for different frequency of incident radiation is shown in the graph. Then



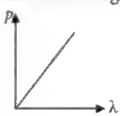
(a) $\upsilon_1 > \upsilon_2 > \upsilon_3$ (b) $\upsilon_3 > \upsilon_2 > \upsilon_1$
(c) $\upsilon_1 = \upsilon_2 > \upsilon_3$ (d) $\upsilon_2 = \upsilon_3 > \upsilon_1$

18. Consider a metal exposed to light of wavelength 600 nm. The maximum energy of the electron doubles when light of wavelength 400 nm is used. The work function of metal in eV is
(a) 1 eV (b) 2 eV
(c) 3 eV (d) 4 eV

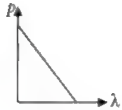
19. Photoelectric emission occurs only when the incident light has more than a certain minimum
(a) frequency (b) power
(c) wavelength (d) intensity

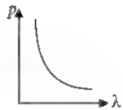
20. In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by
(a) decreasing the potential difference between the anode and filament.
(b) increasing the potential difference between the anode and filament.
(c) increasing the filament current
(d) decreasing the filament current

21. Which of the following graph represents the variation of particle momentum with the associated de Broglie wavelength?

(a) 

(b) 

(c) 

(d) 

22. There are two sources of light, each emitting with a power of 100 W. One emits X-rays of wavelength 1 nm and the other visible light of 500 nm. The ratio of number of photons of X-rays to the photons of visible light of the given wavelength is
(a) 1 : 500 (b) 1 : 400 (c) 1 : 300 (d) 1 : 200

23. A monochromatic source of light emits photons of frequency 6×10^{14} Hz. The power emitted by the source is 8×10^{-3} W. The number of photons emitted per second
(Take $h = 6.63 \times 10^{-34}$ Js)
(a) 6×10^{14} (b) 4×10^{15}
(c) 2×10^{16} (d) 1×10^{17}

24. According to Einstein's photoelectric equation, the graph of kinetic energy of the photoelectron emitted from the metal versus the frequency of the incident radiation gives a straight line graph, whose slope
(a) depends on the intensity of the incident radiation.
(b) depends on the nature of the metal and also on the intensity of incident radiation.
(c) is same for all metals and independent of the intensity of the incident radiation.
(d) depends on the nature of the metal

25. A neutron beam of energy E scatters from atoms on a surface with a spacing $d = 0.1$ nm. The first maximum of intensity in the reflected beam occurs at $\theta = 30°$. The kinetic energy of beam in eV is
(a) 1.23 eV (b) 0.08 eV
(c) 2.43 eV (d) 0.01 eV

26. A photocell is illuminated by a source of light, which is placed at a distance d from the cell. If the distance becomes $d/2$, then number of electrons emitted per second will be
(a) same (b) four times
(c) two times (d) one-fourth

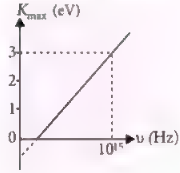
27. A photon of energy E ejects a photoelectron from a metal surface whose work function is ϕ_0. If this electron enters into a uniform magnetic field B in a direction perpendicular to the field and describes a circular path of radius r, then the radius r is (in the usual notation)

(a) $\sqrt{\dfrac{2m(E-\phi_0)}{eB}}$ (b) $\sqrt{2m(E-\phi_0)eB}$

(c) $\dfrac{\sqrt{2e(E-\phi_0)}}{mB}$ (d) $\dfrac{\sqrt{2m(E-\phi_0)}}{eB}$

28. In a photon-particle collision such as photon-electron collision
(a) total energy is conserved
(b) total momentum is conserved
(c) number of photons is conserved
(d) both (a) and (b)

29. Figure represents a graph of kinetic energy of most energetic photoelectrons K_{max} (in eV) and frequency υ for a metal used as cathode in photoelectric experiment. The threshold frequency of light for the photoelectric emission from the metal is



(a) 1×10^{14} Hz
(b) 1.5×10^{14} Hz
(c) 2.1×10^{14} Hz
(d) 2.7×10^{14} Hz

30. The specific charge of a proton is 9.6×10^7 C kg^{-1}. The specific charge of an alpha particle will be
(a) 9.6×10^7 C kg^{-1} (b) 19.2×10^7 C kg^{-1}
(c) 4.8×10^7 C kg^{-1} (d) 2.4×10^7 C kg^{-1}

HIGHER ORDER THINKING SKILLS QUESTIONS (HOTS)

31. Consider a beam of electrons (each electron with energy E_0) incident on a metal surface kept in an evacuated chamber. Then
(a) no electrons will be emitted as only photons can emit electrons.
(b) electrons can be emitted but all with an energy E_0.
(c) electrons can be emitted with any energy, with a maximum of $E_0 - \phi$ (ϕ is the work function).
(d) electrons can be emitted with any energy, with a maximum of E_0.

32. A proton, a neutron, an electron and an α-particle have same energy. Then their de Broglie wavelengths compare as
(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$ (b) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$ (d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

33. An electron (mass m) with an initial velocity $\vec{v} = v_0\,\hat{i}\,(v_0 > 0)$ is in an electric field $\vec{E} = -E_0\,\hat{i}$ (E_0 = constant > 0). It's de Broglie wavelength at time t is given by

(a) $\dfrac{\lambda_0}{\left(1+\dfrac{eE_0t}{mv_0}\right)}$ (b) $\lambda_0\left(1+\dfrac{eE_0t}{mv_0}\right)$

(c) λ_0 (d) $\lambda_0 t$

34. Two monochromatic beams A and B of equal intensity I, hit a screen. The number of photons hitting the screen by beam A is twice that by beam B. Then the frequency υ_A of beam A is related to υ_B of beam B as
(a) $\upsilon_A = 2\upsilon_B$ (b) $\upsilon_B = 2\upsilon_A$
(c) $\upsilon_A = \upsilon_B$ (d) $\upsilon_B = 4\upsilon_A$

35. For a certain metal, incident frequency υ is five times of threshold frequency υ_0 and the maximum velocity of photoelectrons coming out is 8×10^6 m s^{-1}. If $\upsilon = 2\upsilon_0$, the maximum velocity of photoelectrons will be
(a) 4×10^6 m s^{-1} (b) 6×10^6 m s^{-1}
(c) 8×10^6 m s^{-1} (d) 1×10^6 m s^{-1}

SOLUTIONS

1. (c): Kinetic energy of proton, $K = \frac{1}{2}mv^2$

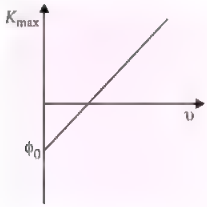
$$= \frac{1}{2m}(mv)^2 = \frac{1}{2m}\left(\frac{h^2}{\lambda^2}\right) \qquad \left(\because \ \lambda = \frac{h}{p}\right)$$

$$= \frac{(6.63\times10^{-34})^2}{2\times1.675\times10^{-27}\times(16.5\times10^{-9})^2}$$

$= 4.82 \times 10^{-25}$ J

2. **(d)** : According to Einstein's photoelectric equation, $K_{max} = h\upsilon - \phi_0$

The graph between K_{max} and υ is a straight line as shown.



$\therefore$ slope of $K_{max} - \upsilon$ graph $= \frac{\Delta K_{max}}{\Delta\upsilon} = h$

Intercept on the negative K_{max} axis $= \phi_0$

$\therefore$ intercept on the negative K_{max} axis gives the value of work function.

The maximum kinetic energy of emitted electrons is independent of the intensity of incident radiation.

3. **(b)** : Photocurrent depends on the intensity of the incident light and is independent of the frequency of incident light.

4. **(c)**: As $K_{max} = \frac{1}{2}mv_{max}^2 = eV_0$

If ϕ_0 is the work function for the given photosensitive surface, then

$eV_1 = h\upsilon_1 - \phi_0 \quad (\because K_{max} = h\upsilon - \phi_0)$ ... (i)

(Given $\upsilon = \upsilon_1$, $V_0 = V_1$)

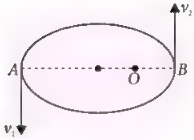
Also, $eV_2 = h\upsilon_2 - \phi_0$ ... (ii)

From equations (i) and (ii), we get

$e(V_2 - V_1) = h(\upsilon_2 - \upsilon_1)$

$$\therefore \ h = \frac{e(V_2 - V_1)}{(\upsilon_2 - \upsilon_1)}$$

5. **(b)** : The de Broglie wavelength of the particle can be varying cyclically between two values λ_1 and λ_2, if particle is moving in an elliptical orbit with origin as its one focus.



Let v_1, v_2 be the speed of particle at A and B respectively and origin is at focus O. If λ_1, λ_2 are the de Broglie wavelengths associated with particle while moving at A and B respectively. Then

$$\lambda_1 = \frac{h}{mv_1} \text{ and } \lambda_2 = \frac{h}{mv_2} \quad \therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{v_2}{v_1}$$

Since $\lambda_1 > \lambda_2 \quad \therefore \quad v_2 > v_1$

From figure we note that origin O is close to B than A.

Thus, option (b) is true.

6. **(a)** : By conservation of linear momentum

$m_1v_1 + m_2v_2 = m \times 0$

or $m_1v_1 = -m_2v_2$ or $|m_1v_1| = |m_2v_2|$

or $|p_1| = |p_2| \quad \therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{p_2}{p_1} = 1$

7. **(d)** : The existence of threshold frequency and the instantaneous emission of photoelectrons support the quantum nature of light.

8. **(a)** : As $h\upsilon = K_{max} + \phi_0 = eV_0 + \phi_0$

$= (6.2 + 5)$ eV $= 11.2$ eV.

Wavelength of incident radiation in Å,

$$\lambda = \frac{hc}{h\upsilon} = \frac{12400 \text{ eV}}{11.2 \text{ eV}} \text{ Å} \approx 1107 \text{ Å}$$

This wavelength lies in the ultraviolet region.

9. **(c)**: Work function, $\phi_0 = \frac{hc}{\lambda_{longest}}$

or $\lambda_{longest} = \frac{hc}{\phi_0} = \frac{(6.63\times10^{-34})\times(3\times10^8)}{4.0\times1.6\times10^{-19}}$

$\approx 310 \times 10^{-9}$ m $= 310$ nm

10. **(b)** : When an electric field is acting vertically downwards, the photoelectron being negatively charged will experience force due to electric field acting vertically upwards, which is the initial direction of motion of emitted photoelectron. Due to which the electron gets accelerated and hence its kinetic energy increases.

11. (b) : According to Einstein's photoelectric equation

$$\frac{hc}{\lambda} = K_{max} + \phi_0$$

where ϕ_0 is a work function of a metal.

$$\therefore \quad K_1 = \frac{hc}{\lambda_1} - \phi_0 \quad \text{...(i)}$$

$$K_2 = \frac{hc}{\lambda_2} - \phi_0 \quad \text{...(ii)}$$

$$\text{or} \quad K_1 - K_2 = hc\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$$

$$= hc\left[\frac{1}{3\lambda_2} - \frac{1}{\lambda_2}\right] = -\frac{2hc}{3\lambda_2} \quad (\because \lambda_1 = 3\lambda_2)$$

$$= -\frac{2}{3}(K_2 + \phi_0) \quad \text{(Using (ii))}$$

$$\text{or} \quad K_1 = K_2 - \frac{2}{3}K_2 - \frac{2}{3}\phi_0 = \frac{K_2}{3} - \frac{2}{3}\phi_0$$

$$\text{or} \quad K_1 < \frac{K_2}{3}$$

12. (c): Kinetic energy of emitted electron

= Energy of incident photon

$$\text{i.e} \quad \frac{1}{2}mv^2 = h\upsilon$$

$$\text{or} \quad \frac{p^2}{2m} = \frac{hc}{\lambda} \quad \left(\because \quad mv = p, \upsilon = \frac{c}{\lambda}\right)$$

$$\text{or} \quad p = \sqrt{\frac{2mhc}{\lambda}}$$

de Broglie wavelength of emitted electrons

$$\lambda' = \frac{h}{p} = \frac{h}{\sqrt{\frac{2mhc}{\lambda}}}$$

$$\text{or} \quad \lambda' = \sqrt{\frac{h\lambda}{2mc}} \quad \therefore \quad \lambda = \frac{2mc}{h}\lambda'^2$$

13. (b) : As $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$ or $\lambda \propto \frac{1}{\sqrt{K}}$

$$\therefore \quad \frac{\lambda'}{\lambda} = \sqrt{\frac{K}{K'}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$$

Percentage change in de Broglie wavelength

$$= \left(\frac{\lambda - \lambda'}{\lambda}\right) \times 100$$

$$= \left(1 - \frac{\lambda'}{\lambda}\right) \times 100 = \left(1 - \frac{1}{4}\right) \times 100 = 75\%$$

14. (d) : Here $\upsilon = 7.21 \times 10^{14}$ Hz,

$v_{max} = 6 \times 10^5$ m s^{-1}

From Einstein's photoelectric equation,

$$K_{max} = \frac{1}{2}mv_{max}^2$$

$$= h\upsilon - \phi_0 = h(\upsilon - \upsilon_0) \quad (\because \phi_0 = h\upsilon_0)$$

$$\therefore \quad (\upsilon - \upsilon_0) = \frac{\frac{1}{2}mv_{max}^2}{h}$$

$$= \frac{1 \times 9.1 \times 10^{-31} \times (6 \times 10^5)^2}{2 \times 6.63 \times 10^{-34}}$$

$$= 2.47 \times 10^{14} \text{ Hz}$$

$$\text{or} \quad \upsilon_0 = \upsilon - 2.47 \times 10^{14}$$

$$= 7.21 \times 10^{14} - 2.47 \times 10^{14}$$

$$= 4.74 \times 10^{14} \simeq 5 \times 10^{14} \text{ Hz}$$

15. (b) : Stopping potential depends on the frequency of incident radiation which remains same because source is same.

$\therefore$ Stopping potential = 0.6 V

Saturation current $\propto$ Intensity of incident radiation.

$$\therefore \quad I_2 = \left(\frac{r_1}{r_2}\right)^2 I_1 = \left(\frac{0.2}{0.6}\right)^2 \times 18 \text{ mA} = 2 \text{ mA}.$$

16. (d) : Kinetic energy of a proton,

$$K = \frac{1}{2}m_p v_p^2 = \frac{p^2}{2m_p}$$

$$\therefore \quad \lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2m_pK}}$$

For photon,

$$K = h\upsilon_2 = \frac{hc}{\lambda_2} \quad \text{or} \quad \lambda_2 = \frac{hc}{K}$$

$$\therefore \quad \frac{\lambda_2}{\lambda_1} = \frac{hc}{K} \cdot \frac{\sqrt{2m_pK}}{h} = c\sqrt{\frac{2m_p}{K}}$$

$$\text{or} \quad \frac{\lambda_2}{\lambda_1} \propto K^{-1/2}$$

17. (b) : The stopping potential is more negative for higher frequency of incident radiation.

18. (a) : As $K_{max} = h\upsilon - \phi_0 = \frac{hc}{\lambda} - \phi_0$

As per question,

$$\left(\frac{hc}{\lambda_1}-\phi_0\right)=\frac{1}{2}\left(\frac{hc}{\lambda_2}-\phi_0\right)$$

or $\dfrac{2hc}{\lambda_1}-2\phi_0=\dfrac{hc}{\lambda_2}-\phi_0$

or $\phi_0=hc\left[\dfrac{2}{\lambda_1}-\dfrac{1}{\lambda_2}\right]$

$=1240\text{ eV nm}\left[\dfrac{2}{600\text{ nm}}-\dfrac{1}{400\text{ nm}}\right]$

$(\because hc=1240\text{ eV nm})$

$=1.033\text{ eV}\simeq 1\text{ eV}$

19. (a) : As $\frac{1}{2}mv^2=h(\upsilon-\upsilon_0)$,

For photoelectric emission, $\upsilon\geq\upsilon_0$.

20. (b)

21. (d) : As $\lambda=\frac{h}{p}$, or λp = constant, so graph between λ and p is a rectangular hyperbola, which is option (d).

22. (a) : Here, P = 100 W, λ_1 = 1 nm, λ_2 = 500 nm

Let n_1 and n_2 be the number of photons of X-rays and visible light emitted from the two sources

$\therefore\quad n_1\dfrac{hc}{\lambda_1}=n_2\dfrac{hc}{\lambda_2}$

or $\dfrac{n_1}{\lambda_1}=\dfrac{n_2}{\lambda_2}$ or $\dfrac{n_1}{n_2}=\dfrac{\lambda_1}{\lambda_2}=\dfrac{1}{500}$

23. (c): Energy of photon, $E=h\upsilon$

$E=(6.63\times10^{-34}\text{ J s})(6\times10^{14}\text{ Hz})$

$=39.8\times10^{-20}$ J

Power of the source, $P=8\times10^{-3}$ W

Number of photons emitted per second is

$$N=\frac{P}{E}=\frac{8\times10^{-3}\text{ W}}{39.8\times10^{-20}\text{ J}}=2\times10^{16}$$

24. (c): According to Einstein's photoelectric equation

Maximum kinetic energy, $K_{max}=h\upsilon-\phi_0$

where, h = Planck's constant

υ = Frequency of incident light

ϕ_0 = Work function of a metal

Compare it with the equation of straight line

$y=mx+c$

we get, slope of the graph = h

25. (b) : Here, d = 0.1 nm, $\theta=30°$, n = 1

By Bragg's law, $2d\sin\theta=n\lambda$

or $2\times0.1\text{ nm}\times\sin30°=1\times\lambda$

$\therefore\quad\lambda=0.1\text{ nm}=10^{-10}$ m

As $p=\dfrac{h}{\lambda}=\dfrac{6.63\times10^{-34}}{10^{-10}}=6.63\times10^{-24}\text{ kg m s}^{-1}$

Kinetic energy

$=\dfrac{1}{2}\dfrac{p^2}{m}=\dfrac{(6.63\times10^{-24})^2}{2\times1.67\times10^{-27}\times1.6\times10^{-19}}$

$=0.082$ eV

26. (b) : Number of photons emitted per second $N\propto$ intensity of incident light

$\propto\dfrac{1}{d^2}$.

When d becomes $\dfrac{d}{2}$, N becomes $4N$.

27. (d) : As the electron describes a circular path of radius r in the magnetic field, therefore

$\dfrac{mv^2}{r}=evB$

$r=\dfrac{mv}{eB}=\dfrac{p}{eB}=\dfrac{\sqrt{2mK}}{eB}\quad\left(\because K=\dfrac{p^2}{2m}\right)$

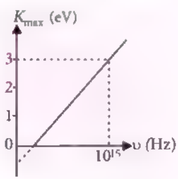
From Einstein's photoelectric equation

$K=E-\phi_0$

$\therefore\quad r=\dfrac{\sqrt{2m(E-\phi_0)}}{eB}$

28. (d) : In a photon-electron collision, the total energy and total momentum are conserved. However, the number of photons may not be conserved in collision. The photon may be absorbed or a new photon may be created.

29. (d) :



From graph, $\upsilon=10^{15}$ Hz,

$K_{max}=3\text{ eV}=3\times1.6\times10^{-19}$ J

According to Einstein's photoelectric equation

$K_{max} = h\upsilon - h\upsilon_0$

or $h\upsilon_0 = h\upsilon - K_{max}$

or $\upsilon_0 = \upsilon - \frac{K_{max}}{h} = 10^{15} - \frac{3\times1.6\times10^{-19}}{6.63\times10^{-34}}$

$= (10 - 7.3)\times 10^{14} = 2.7\times10^{14}$ Hz.

30. (c): For proton, specific charge $= \frac{e}{m}$

$= 9.6\times10^7$ C kg^{-1}

For alpha particle,

specific charge $= \frac{2e}{4m} = \frac{1}{2}\frac{e}{m}$

$= \frac{1}{2}\times9.6\times10^7 = 4.8\times10^7$ C kg^{-1}.

31. (d) : When a beam of electrons of energy E_0 is incident on a metal surface kept in an evacuated chamber, electrons can be emitted with maximum energy E_0 (due to elastic collision) and with any energy less than E_0, when part of incident energy of electron is used in liberating the electrons from the surface of metal.

32. (b) : Kinetic energy of particle, $K = \frac{1}{2}mv^2$

or $mv = \sqrt{2mK}$

de Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

For the given value of K, $\lambda \propto \frac{1}{\sqrt{m}}$

$\therefore \lambda_p : \lambda_n : \lambda_e : \lambda_\alpha = \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{m_n}} : \frac{1}{\sqrt{m_e}} : \frac{1}{\sqrt{m_\alpha}}$

Since $m_p = m_n$, hence $\lambda_p = \lambda_n$

As $m_\alpha > m_p$, therefore $\lambda_\alpha < \lambda_p$

As $m_e < m_n$, therefore $\lambda_e > \lambda_n$

Hence $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$

33. (a) : Here, $\vec{E} = -E_0\hat{i}$; initial velocity $\vec{v} = v_0\hat{i}$

Force acting on electron due to electric field

$\vec{F} = (-e)(-E_0\hat{i}) = eE_0\hat{i}$

Acceleration produced in the electron,

$\vec{a} = \frac{\vec{F}}{m} = \frac{eE_0}{m}\hat{i}$

Now, velocity of electron after time t,

$\vec{v}_t = \vec{v} + \vec{a}\,t = \left(v_0 + \frac{eE_0 t}{m}\right)\hat{i}$

or $|\vec{v}_t| = v_0 + \frac{eE_0 t}{m}$

Now,

$\lambda_t = \frac{h}{mv_t} = \frac{h}{m\left(v_0 + \frac{eE_0 t}{m}\right)} = \frac{h}{mv_0\left(1 + \frac{eE_0 t}{mv_0}\right)}$

$= \frac{\lambda_0}{\left(1 + \frac{eE_0 t}{mv_0}\right)}$ $\quad \left(\because \lambda_0 = \frac{h}{mv_0}\right)$

34. (b) : Let n_A and n_B be the number of photons falling per second of beam A and B respectively.

Energy of falling photon of beam $A = h\upsilon_A$

Energy of falling photon of beam $B = h\upsilon_B$

From question,

intensity of A = intensity of B

$\therefore\ n_A h\upsilon_A = n_B h\upsilon_B$

or $\frac{\upsilon_A}{\upsilon_B} = \frac{n_B}{n_A} = \frac{n_B}{2n_B} = \frac{1}{2}$ $\quad (\because n_A = 2n_B)$

$\therefore\ \upsilon_B = 2\upsilon_A$

35. (a) : According to Einstein's photoelectric equation

$h\upsilon = h\upsilon_0 + \frac{1}{2}mv_{max}^2$ or $\frac{1}{2}mv_{max}^2 = h\upsilon - h\upsilon_0$

According to the given problem

$\frac{1}{2}m(8\times10^6)^2 = h(5\upsilon_0 - \upsilon_0)$ ...(i)

$\frac{1}{2}mv_{max}^2 = h(2\upsilon_0 - \upsilon_0)$ ...(ii)

Dividing equation (i) by (ii), we get

$\frac{(8\times10^6)^2}{v_{max}^2} = \frac{4\upsilon_0}{\upsilon_0} \Rightarrow v_{max}^2 = \frac{(8\times10^6)^2}{4}$

$v_{max} = \frac{8\times10^6}{2} = 4\times10^6$ m s^{-1}

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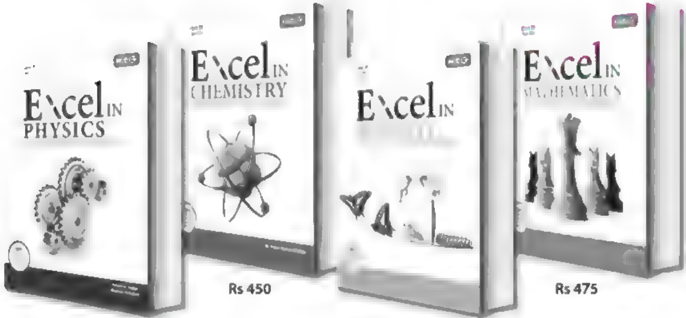

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Q1. Suppose scientists had chosen to measure small energies in proton volts rather than electron volts. What difference would this make?

- Pratibha Sharma, Agra (U.P.)

Ans. There would be no difference at all. An electron volt is the kinetic energy gained by an electron that is accelerated through a potential difference of one volt. A proton accelerated through one volt will have the same kinetic energy because it carries a charge of the same magnitude as the electron. The proton will be moving slowly after accelerating through one volt due to its larger mass, but it will still gain one electron volt or one proton volt of kinetic energy.

Q2. Does an automobile speedometer measure average or instantaneous speed?

– Manjri Saha (W.B.)

Ans. Based on the fact that changes in the speed of the automobile are reflected as changes in the speedometer reading, we might be tempted to say that a speedometer measures instantaneous speed. This would not be quite correct, however. The reading on a speedometer is related to the rotation of wheels. Often, a rotating magnet, whose rotation is related to that of the wheels, is used in a speedometer. The reading is based on the time interval between rotations of the magnet. Thus, the reading is an average speed over this interval. This interval is generally very short, so that the average speed over the interval is a good approximation to the instantaneous speed at any instant within the interval. As long as the changes in speed are gradual, this approximation is very good. If the automobile brakes to a quick stop, however, the speedometer may not able to keep up with the rapid changes in speed, and the measured average speed over the time interval may be different from the instantaneous speed at the end of the interval.

Q3. In the absence of air friction, it is claimed that all objects fall with the same acceleration. A heavier object is pulled to the Earth with more force than a light object. Why does the heavier object not fall faster?

- Prateek Shukla (New Delhi)

Ans. It is indeed true that the heavier object is pulled with a larger force. The strength of the force is determined by the gravitational mass of the object. The resistance to the force and, therefore, to the change in motion of the object, is represented by the inertial mass. Thus, if an object has twice as much mass as another, it is pulled to the Earth with twice the force, but it also exhibits twice the resistance of having its motion changed. These factors cancel, so that the change in motion, the acceleration, is the same for all objects, regardless of mass.

Q4. A boy stands at one end of a canoe that is stationary relative to the shore. He then walks to the opposite end of the canoe, away from the shore. Does the canoe move?

– T.R. Rajesh, Kochi (Kerala)

Ans. Yes, the canoe moves toward the shore. Ignoring friction between the canoe and water, no horizontal force acts on the system consisting of the boy and canoe. The centre of mass of the system therefore remains fixed relative to the shore (or any stationary point). As the boy moves away from the shore, the canoe must move toward the shore such that the center of mass of the system remains fixed in position.

Q5. Suppose you run past your stereo speakers, from right to left, or left to right. If you run rapidly enough and have excellent pitch discrimination, you may notice that the music that is playing seems to be out of tune when you are between the speakers. Why?

– Abhinav Jha (Bihar)

Ans. When you are between the speakers, you are running away from one of them and toward the other. Thus, there is a Doppler shift downward for the sound from the speaker behind you and a Doppler shift upward for the sound from the speaker ahead of you. As a result, the sound from the two speakers will not be in tune. A calculation shows that a world-class sprint runner could run fast enough to generate about a semitone difference in the sound from the two speakers.

Q6. The plumes from some erupting volcanoes, such as the Sakurajima volcano in Japan, develop electrical discharges that flash over the crater, lighting up the sky and sending out sound waves that resemble thunder. What causes these sound-and-light shows?

– Stefan George (Goa)

Ans. The discharges are due to charged particles carried aloft by the plumes rising from or shot from a volcano. The plume may be dominated by positive charge, but usually it also contains regions of negative charge. These regions can discharge to one another or to ground. The current in a discharge can heat the air so intensely that the air expands faster than the speed of sound, such expansion send out a shock wave, which reaches an observer (who is at, hopefully, a safe distance) as a loud boom.

Several effects might account for the charged particles being in the plumes : (i) If water suddenly encounters molten lava, it can bead up in what is called the Leidenfrost effect, floating on a vapour layer. Any such large drop quickly splits into charged smaller drops, which are then carried into the atmosphere by the rising plume of hot air and water vapour. (ii) Magma becomes charged when it fractures as it either hits water or crashes through the upper end of the volcano conduit and then is ejected in the plume. Once the charged particles are aloft, collisions can transfer charge from one particle to another or even cause additional charging, as occurs in wind-blown dust.

PHYSICS MUSING

SOLUTION SET-11

1. (a) : Given : $dQ = -dU$

or $nCdT = -nC_V dT$

$$\Rightarrow \quad C = -C_V = -\frac{R}{(\gamma-1)}$$

According to first law of thermodynamics,

$$dQ = dU + dW$$

$\therefore \quad 2dQ = dW \qquad (\because dQ = -dU)$

or $\quad 2nCdT = \frac{nRT}{V}dV$

$$\frac{dT}{T} = \frac{R}{2C}\frac{dV}{V}$$

Integrating both sides, we get

$$\ln T = \frac{R}{2C}\ln V + C_1$$

or $\quad \ln T = \ln V^{R/2C} + C_1$

or $\quad \ln\left(\frac{T}{V^{R/2C}}\right) = C_1$

or $\quad TV^{-R/2C} = \text{constant}$

or $\quad TV^{\frac{\gamma-1}{2}} = \text{constant}$

$$\left(\because \frac{-R}{2C} = \frac{+R(\gamma-1)}{2R} = \frac{\gamma-1}{2}\right)$$

Given : $TV^{1/5} = \text{constant}$

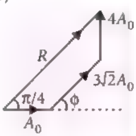
So, $\frac{\gamma-1}{2} = \frac{1}{5} \quad \Rightarrow \quad \gamma = \frac{7}{5}$

2. (c): Given, $y_1 = A_0 \sin(kx - \omega t)$

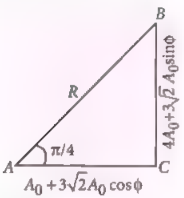
$y_2 = 3\sqrt{2}A_0 \sin(kx - \omega t + \phi)$,

and $y_3 = 4A_0 \cos(kx - \omega t)$,

These waves can be represented by phase diagram as shown.



From phase diagram,



$$\tan\left(\frac{\pi}{4}\right) = \frac{BC}{AC} = \frac{A_0(4+3\sqrt{2}\sin\phi)}{A_0(1+3\sqrt{2}\cos\phi)}$$

$$\Rightarrow \quad 4+3\sqrt{2}\sin = 1+3\sqrt{2}\cos\phi$$

$$\Rightarrow \quad \cos\phi - \sin\phi = \frac{1}{\sqrt{2}}$$

Squaring both sides, we get

$$\cos^2\phi + \sin^2\phi - 2\sin\phi\cos\phi = \frac{1}{2}$$

$$1 - 2\sin\phi\cos\phi = \frac{1}{2}$$

or $\quad 2\sin\phi\cos\phi = \frac{1}{2}$

or $\quad \sin 2\phi = \frac{1}{2} = \sin\frac{\pi}{6}$

or $\quad 2\phi = \frac{\pi}{6} \quad \Rightarrow \quad \phi = \frac{\pi}{12}$

3. (d) : As volume of gas remains constant,

$\therefore$ Heat given = change in internal energy

$qdt = nC_V dT$

$\therefore \quad \frac{dT}{dt} = \frac{q}{nC_V}$ and $VdP = nRdT$

$$\therefore \quad \frac{dT}{dt} = \frac{V}{nR}\frac{dP}{dt}$$

$$\frac{V}{nR}\frac{dP}{dt} = \frac{q}{nC_V}$$

$$\therefore \quad \frac{g}{A}\frac{dm}{dt} = \frac{qR}{VC_V}$$

$$\Rightarrow \quad \frac{dm}{dt} = \frac{qRA}{gV(3/2)R} = \frac{2qA}{3gV} = \frac{2\times30\times0.1}{3\times10\times5}$$

$$= 0.04 \text{ kg s}^{-1}$$

4. (c): At any instant, $T = T_0 + \alpha V$ ...(i)

$$\therefore \quad C = \frac{3R}{2} + \frac{R(T_0+\alpha V)}{V}\frac{1}{\alpha} = \frac{3R}{2} + \frac{RT_0}{\alpha V} + R$$

$$= \frac{5R}{2} + \frac{RT_0}{\alpha V}$$

$$\therefore \quad \Delta Q=(1)\int\left(\frac{5R}{2}+\frac{RT_0}{\alpha V}\right)dT$$

$$=\alpha\int_{V_0}^{2V_0}\left(\frac{5R}{2}+\frac{RT_0}{\alpha V}\right)dV$$

($\because$ $dT=\alpha dV$ using ... (i))

$$=\frac{5R\alpha V_0}{2}+RT_0\ln 2$$

5. **(a)** : $\phi_1=\frac{\mu_0 Ia}{2\pi}\int_0^a\frac{dr}{a+r}=\frac{\mu_0 Ia}{2\pi}\ln 2$

$$\phi_2=\frac{\mu_0 Ia}{2\pi}\int_0^a\frac{r\,dr}{r^2+a^2}=\frac{\mu_0 Ia}{4\pi}\ln 2$$

$$=\frac{\mu_0 Ia}{2\pi}\ln\sqrt{2}$$

$$\Rightarrow \quad \Delta\phi=\frac{\mu_0 Ia}{2\pi}(\ln 2-\ln\sqrt{2})=\frac{\mu_0 Ia}{2\pi}\ln\sqrt{2}$$

$$\therefore \quad \Delta Q=\frac{\Delta\phi}{R}=\frac{\mu_0 Ia}{2\pi R}\ln\sqrt{2}$$

6. **(b)** : The force is perpendicular to the radius vector $\vec{R}=x\hat{i}+y\hat{j}$

$\Rightarrow$ Force is tangential

Torque, $|\vec{\tau}|=R|\vec{F}|=R\sqrt{x^2+y^2}=R^2$

$$W=\int_0^{\theta}\tau\,d\theta=R^2 2\pi$$

$\therefore$ $R^2 2\pi=32\pi \Rightarrow R=4$ m

7. **(b)** : $g=\frac{4\pi^2 L}{T^2}$

Percentage error in g,

$$\left(\frac{\Delta g}{g}\right)\times 100\%=\left[\left(\frac{\Delta L}{L}\right)+2\times\left(\frac{\Delta T}{T}\right)\right]\times 100\%$$

$$\frac{\Delta L}{L}=\frac{0.1\text{ cm}}{10\text{ cm}}=0.01$$

$$\frac{\Delta T}{T}=\frac{\Delta t}{t}=\frac{1\text{ s}}{0.5\times 100\text{ s}}=0.02$$

$\therefore$ Percentage error in g

$=(0.01+2\times 0.02)\times 100\%$

$=0.05\times 100\%=5\%$

8. **(b)** : As, $I_R=I_1+I_2+2\sqrt{I_1I_2}\cos\phi$

Here $I_1=I$, $I_2=4I$

At A, $\phi=\pi/2 \Rightarrow I_{RA}=5I$

At B, $\phi=\pi \Rightarrow I_{RB}=I$

$\therefore$ $I_{RA}-I_{RB}=4I$

9. **(a)** : Let f_a and f_w be the focal lengths of the lens in air and water respectively, then

$$P_a=\frac{1}{f_a} \quad\text{and}\quad P_w=\frac{\mu_w}{f_w}$$

$f_a=0.2$ m $=20$ cm

Using lens maker's formula

$$P_a=\frac{1}{f_a}=(\mu_g-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad ...(i)$$

$$\text{and} \quad \frac{1}{f_w}=\left(\frac{\mu_g}{\mu_w}-1\right)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\Rightarrow \quad P_w=\frac{\mu_w}{f_w}=(\mu_g-\mu_w)\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad ...(ii)$$

Dividing equation (ii) by equation (i), we get,

$$\frac{P_w}{P_a}=\frac{(\mu_g-\mu_w)}{(\mu_g-1)}=\frac{\left(\frac{3}{2}-\frac{4}{3}\right)}{\left(\frac{3}{2}-1\right)}=\frac{1}{3}$$

$$\text{or} \quad P_w=\frac{P_a}{3}=\frac{5}{3}\text{D}$$

10. **(b)** : Number of fringes $=\frac{\text{length of region}}{\text{fringe width}}$

We know that,

Fringe width $\propto$ wavelength

$\therefore$ No. of fringes, $n\propto\frac{1}{\text{wavelength, }\lambda}$

or $n_1\lambda_1=$ constant

(For other parameters constant)

$\therefore$ $12\times 600=x\times 400$

$\therefore$ $x=18$

Solution Senders of Physics Musing

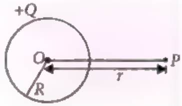
SET-11

1. Arun Nayan (U.P)
2. Nesa Mirza (W.B)
3. Khwaja Sami Baig (U.P)

Contd. from page no. 25

4. **(c)**: Electric field due to uniformly charged dielectric solid sphere of radius R at a point P is given by

$$E = \begin{cases} k \cdot \dfrac{Q}{R^3} \cdot r, & r \le R \\ k \cdot \dfrac{Q}{r^2}, & r > R \end{cases}$$



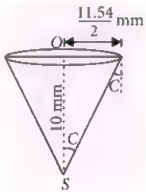
For solid sphere 1, $E_1 = \dfrac{kQ}{R^2}$

For solid sphere 2, $E_2 = \dfrac{k(2Q)}{R^2} = 2E_1$

For solid sphere 3, $E_3 = \dfrac{k(4Q)R}{(2R)^3} = \dfrac{kQ}{2R^2} = \dfrac{E_1}{2}$

$\therefore \quad E_2 > E_1 > E_3$

5. **(c)**: Given situation is shown in the figure (not to the scale)



Suppose μ_l = refractive index of liquid
μ_b = refractive index of block = 2.72
C = critical angle

This situation is seen as if there is phenomena of total internal reflection of light.

$$\therefore \quad \sin C = \frac{\mu_l}{\mu_b} = \frac{\mu_l}{2.72} \qquad \text{... (i)}$$

From figure,

$$\sin C = \frac{\dfrac{11.54}{2}}{\sqrt{\left(\dfrac{11.54}{2}\right)^2 + 10^2}}$$

$$\Rightarrow \frac{\mu_l}{2.72} = \frac{5.77}{11.545} \qquad \text{(Using eqn. (i))}$$

$\Rightarrow \mu_l \approx 1.36$

6. **(a)** : In steady state, $H = \sigma A(T^4 - T_0^4)$

$\Rightarrow I(\pi R^2) = \sigma(T^4 - T_0^4)(4\pi R^2)$

or $I = 4\sigma(T^4 - T_0^4)$

Here, $I = 912\ \text{W m}^{-2}$, $T_0 = 300$ K,
$\sigma = 5.7 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-2}$,

$\therefore \quad 912 = 4(5.7 \times 10^{-8})(T^4 - (300)^4)$

$\Rightarrow T^4 - (300)^4 = 40 \times 10^8$

$\Rightarrow T^4 = 121 \times 10^8$

or $T = 331.66\ \text{K} \approx 330\ \text{K}$

7. **(a)** : From Einstein's photoelectric equation, kinetic energy of photoelectrons,

$$K = \frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi \qquad \text{... (i)}$$

For $\lambda = 248$ nm, $v = u_1$

$$\therefore \quad K_1 = \frac{1}{2}mu_1^2 = \frac{hc}{248} - \phi \qquad \text{... (ii)}$$

For $\lambda = 310$ nm, $v = u_2$

$$\therefore \quad K_2 = \frac{1}{2}mu_2^2 = \frac{hc}{310} - \phi \qquad \text{... (iii)}$$

Divide eqn. (ii) by eqn. (iii),

$$\frac{u_1^2}{u_2^2} = \frac{\dfrac{hc}{248} - \phi}{\dfrac{hc}{310} - \phi} = \frac{\dfrac{1240}{248} - \phi}{\dfrac{1240}{310} - \phi}$$

$$\Rightarrow \left(\frac{2}{1}\right)^2 = \frac{5 - \phi}{4 - \phi}$$

$\Rightarrow 16 - 4\phi = 5 - \phi \Rightarrow 3\phi = 11$

or $\phi = 3.67\ \text{eV} \approx 3.7\ \text{eV}$

8. **(b)** : Using Moseley's law for K_α X-ray lines

$\sqrt{\upsilon} = a(Z - b)$, where $b = 1$

$$\text{Thus,} \quad \sqrt{\frac{c}{\lambda_{Cu}}} = a(29 - 1) \qquad \text{... (i)}$$

$$\text{and} \quad \sqrt{\frac{c}{\lambda_{Mo}}} = a(42 - 1) \qquad \text{... (ii)}$$

Dividing eqn. (ii) by (i)

$$\sqrt{\frac{\lambda_{Cu}}{\lambda_{Mo}}} = \frac{a(42-1)}{a(29-1)} = \frac{41}{28}$$

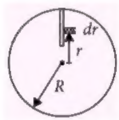
$$\Rightarrow \frac{\lambda_{Cu}}{\lambda_{Mo}} = \left(\frac{41}{28}\right)^2 = 2.14$$

9. **(b)** : Gravitational field inside the planet at a distance r from centre,

$$g_i = \frac{GM}{R^3}r = \frac{G\left(\frac{4}{3}\pi R^3\right)\rho}{R^3}r = \frac{4}{3}G\pi r\rho$$

Force applied by a person on the wire at rest is the weight of the wire. Since, gravitational field is variable so force on each part of the wire is different.

Consider a small portion dr of the wire at a distance r from centre of the planet, so its weight will be



$$dW = (dm)g_i$$

$$= (\lambda dr)\left(\frac{4}{3}G\pi r\rho\right)$$

$$= \left(\frac{4}{3}G\pi\rho\right)(\lambda r dr)$$

Net weight, $W = \int dW = \left(\frac{4}{3}G\pi\rho\lambda\right)\int_{\left(\frac{4R}{5}\right)}^{R} r dr$

$$W = \left(\frac{4}{3}G\pi\rho\lambda\right)\left(\frac{9}{50}\right)R^2 \quad \text{... (i)}$$

Density of the Earth, $\rho = \dfrac{M_E}{\frac{4}{3}\pi R_E^3}$

Also, $R = \dfrac{R_E}{10}$

Putting the values of ρ and R in equation (i), we get

$$W = \left(\frac{9}{5\times 10^3}\right)g_E\lambda R_E$$

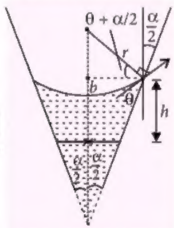
$$= \frac{9}{5\times 10^3}\times 10\times 10^{-3}\times 6\times 10^6 = 108 \text{ N}$$

So, net force applied by the person to hold the wire = 108 N.

10. (d) : Let r = radius of curvature of meniscus

$$b = r\cos\left(\theta + \frac{\alpha}{2}\right)$$

Excess pressure on concave side of meniscus



$$= \frac{2S}{r}$$

$$\Rightarrow (P_0 + h\rho g) - P_0 = \frac{2S}{r}$$

$$\Rightarrow h\rho g = \frac{2S\cos\left(\theta + \frac{\alpha}{2}\right)}{b}$$

or $\quad h = \dfrac{2S}{b\rho g}\cos\left(\theta + \dfrac{\alpha}{2}\right)$

11. (d) : Suppose final temperature of gases = T

Heat rejected by gas in lower compartment

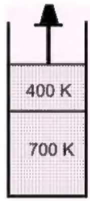
$= nC_V\Delta T$ (As volume is fixed.)

$$= 2\times\frac{3}{2}R(700 - T) \quad \text{... (i)}$$

Heat received by gas in upper compartment,

$= nC_P\Delta T$ (as piston is movable, so pressure is constant)

$$= 2\times\frac{7}{2}R(T - 400) \quad \text{... (ii)}$$



Equating eqn. (i) and (ii),

$$2\times\frac{3}{2}R(700 - T) = 2\times\frac{7}{2}R(T - 400)$$

$\Rightarrow$ $3(700 - T) = 7(T - 400)$

$\Rightarrow$ $2100 - 3T = 7T - 2800$

$\Rightarrow$ $10T = 4900$ or $T = 490$ K

12. (d) : Let equilibrium temperature of the gases in the two compartments = T

Pressure of the gases in each compartment is constant and same.

Heat given by lower compartment

$$= nC_P\Delta T$$

$$= 2\times\frac{5}{2}R(700 - T) \quad \text{... (i)}$$

Heat taken by upper compartment

$$= nC_P\Delta T$$

$$= 2\times\frac{7}{2}R(T - 400) \quad \text{... (ii)}$$

Equating eqn. (i) and (ii),

$5R(700 - T) = 7R(T - 400)$

$\Rightarrow$ $3500 - 5T = 7T - 2800$

$\Rightarrow$ $12T = 6300$ or $T = 525$ K

In isobaric process, work done by gas,

$\Delta W = nR\Delta T$

For lower compartment,

$\Delta W_1 = 2R(525 - 700) = -350R$

For upper compartment,

$\Delta W_2 = 2R(525 - 400) = 250R$

Net work done by gases to attain equilibrium

$= \Delta W_1 + \Delta W_2 = -100R$

13. (c): Using equation of continuity,

$a_1v_1 = a_2v_2$

Here, $r_1 = 20$ mm $= 20\times 10^{-3}$ m

$v_1 = 5 \text{ mm s}^{-1} = 5 \times 10^{-3} \text{ m s}^{-1}$
$r_2 = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}, v_2 = ?$

$$v_2 = \frac{a_1 v_1}{a_2} = \frac{\pi r_1^2 v_1}{\pi r_2^2}$$

$$\Rightarrow v_2 = \frac{(20\times10^{-3})^2(5\times10^{-3})}{(1\times10^{-3})^2}$$

$$= 400 \times 5 \times 10^{-3} = 2 \text{ m s}^{-1}$$

14. (a) : Pressure at the point A in the nozzle is P.

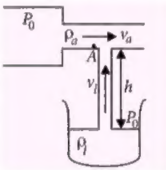
Now, $P = P_0 - \frac{1}{2}\rho_a v_a^2$ ... (i)

and also $P = P_0 - \frac{1}{2}\rho_l v_l^2 - \rho_l gh$ ... (ii)

From eqn. (i) and (ii),

$$\frac{1}{2}\rho_a v_a^2 = \frac{1}{2}\rho_l v_l^2 + \rho_l gh$$

$$\Rightarrow v_l = \sqrt{\frac{\rho_a}{\rho_l}v_a^2 - 2gh}$$

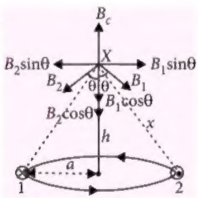


So for given v_a and h,

$$v_l \propto \sqrt{\frac{\rho_a}{\rho_l}} \quad \text{or} \quad (av_l) \propto \sqrt{\frac{\rho_a}{\rho_l}}$$

where a = area of cross-section of thin tube.
So, correct option is (a).

15. (c):



Let magnetic field due to ciruclar loop = $\vec{B}_c$

Magnetic field due to wire 1 = $\vec{B}_1$

Magnetic field due to wire 2 = $\vec{B}_2$

In magnitude, $B_1 = B_2 = \frac{\mu_0 I}{2\pi x}$

So, $B_1\sin\theta$ and $B_2\sin\theta$ cancelled each other.

Resultant of B_1 and $B_2 = B_1\cos\theta + B_2\cos\theta$

$$= 2B_1\cos\theta = \frac{2\mu_0 I}{2\pi x}\times\frac{h}{x} = \frac{\mu_0 Ih}{\pi x^2}$$

(From figure, $\cos\theta = h/x$)

$$= \frac{\mu_0 Ih}{\pi(a^2+h^2)}$$

$$B_c = \frac{\mu_0 Ia^2}{2(a^2+h^2)^{3/2}}$$

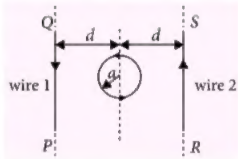
For zero magnetic field at X,

$$\frac{\mu_0 Ih}{\pi(a^2+h^2)} = \frac{\mu_0 Ia^2}{2(a^2+h^2)^{3/2}}$$

$$\Rightarrow \frac{h}{\pi} = \frac{a^2}{2\sqrt{a^2+h^2}} \Rightarrow h \approx 1.2\,a$$

16. (b) : The magnitude of torque on the loop is given by

$$\tau = MB\sin\theta$$



Here, $M = IA = I(\pi a^2)$

$B = 2\times\frac{\mu_0 I}{2\pi d}$ (net magnetic field at the mid point of the loop)

$\theta = 30°$

$$\tau = I(\pi a^2)\times\frac{\mu_0 I}{\pi d}\times\sin 30°$$

$$= \frac{\mu_0 I^2 a^2}{2d}$$

17. (a) **18.** (b) **19.** (d) **20.** (c)